FireWorks Curriculum For Middle School

Featuring Lower and Upper Sierra Nevada Mixed Conifer Forests

2017

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Produced by:

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August, 2017

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The *FireWorks* program was originally completed and the curriculum published in 2000 (Smith and McMurray 2000). This version incorporates new science, new teaching techniques, and new standards, and is adapted for Sierra Nevada ecosystems.

***FireWorks*: Why?**

Change is an integral part of a healthy, enduring ecosystems in most temperate regions of the world. *FireWorks* provides students with interactive, hands-on materials to study the forces that cause change, particularly wildland fire. The program is based on the science of wildland fire, a highly interdisciplinary field, so it provides a context for learning about properties of matter, chemical and physical processes, ecosystem fluctuations and cycles, habitat and survival, and human interactions with ecosystems. These concepts are considered important for science literacy (American Association for the Advancement of Science 1993). Students using *FireWorks* ask questions, gather information, analyze and interpret it, and communicate their discoveries. They often work in pairs or small groups. These are learning styles that enhance understanding, cognitive skills, and social skills (Moreno 1999; National Research Council 1996).

Goals

FireWorks aims to increase understanding

- of the physical science of combustion, especially in wildland fuels
- that an ecosystem has many kinds of plants and animals, which change over time and influence one another
- that fire is an important natural process in many ecosystems
- that native plants and animals have ways to survive fire or reproduce after fire, or both
- that people influence the fire-dependent ecosystems where they live, and they always have done so

Meeting these goals helps implement the vision of the National Cohesive Wildland Fire Management Strategy (U.S. Department of Agriculture, Forest Service; Department of the Interior, Office of Wildland Fire Coordination. 2011) "*To safely and effectively extinguish fire when needed; use fire where allowable; manage our natural resources; and as a nation, to live with wildland fire*."

FireWorks also aims to increase student skills in

- making observations
- classifying information
- measuring, counting, and computing
- stating and testing hypotheses

- describing observations, both qualitatively and quantitatively
- explaining reasoning
- identifying and expressing responses to science-related questions
- working in teams to solve problems and
- critical listening and reading

These skills are crucial for developing an adult citizenry literate in science and attracting students to professional work in the sciences (National Research Council 1996).

Local learning:

Students learn best about ecology when it is close to home—when they can study the plants, animals, and fire regimes typical of local ecosystems (Lindholdt 1999; North American Association for Environmental Education 1999).

This version of *FireWorks* focuses on selected *ecological communities* in the Sierra Nevada–forests dominated by conifers. These communities are often called lower and upper *mixed conifer* or lower and upper *montane* communities. These lower and upper montane mixed-conifer forests have a long, intimate relationship with fire. The photo presentation created for Activity 1 in the Elementary and Middle School curricula shows many inhabitants of these communities and the different types of fire that occur in them.

Lower montane forests grow just uphill from the grassy and shrubby *foothill* communities in the Sierra Nevada. Thus they occur at relatively low elevations, not high in the mountains. Lower montane forests are dominated by oaks, ponderosa pine, sugar pine, white fir, Douglas-fir, and incense-cedar. Many of these forests, especially in historical times, were dominated by pines. They had an open structure, with old, large trees spaced far apart and a few young trees. They had many kinds of grasses, wildflowers, and shrubs in the understory. A few of these old-growth, pine-dominated forests remain today. In the past, fires in this kind of forest tended to spread through the surface fuels. They rarely jumped into the tree crowns. Even when they did, they could not spread from crown to crown because most of the trees were spaced far apart. Because these forests are relatively dry, they typically burned frequently. Repeated fires keep the forest structure open. They favor grasses, wildflowers, and shrubs that can sprout easily after fire, and they provide habitat for mammals and birds that need large, old trees and an open understory.

Upper montane forests occur at fairly high elevations, but not all the way up on mountainsides. These forests are usually dominated by Jeffrey pine, red fir, and lodgepole pine. There is a lot of overlap between lower and upper montane forests, so species from these communities often intermix. Because upper montane forests grow higher in the mountains, they are colder, receive more snow, and have a shorter growing season. Thus historical fires generally burned less frequently than in lower montane communities, although there is considerable variability. In the past, fires in upper montane forests tended to spread through the surface fuels but sometimes also jumped into the tree crowns. Fires killed trees in small patches, but most large trees survived.

Mixed-conifer forests in the Sierra Nevada have experienced very few low-severity fires in the past century. Because of this, the forests tend to be very dense and have a lot of litter, logs, and *ladder fuels* (shrubs and young trees that increase in the absence of fire and enable fires burning on the forest floor to climb into the tree tops). The forest canopy is fairly continuous (*closed*), and trees that grow well in shade are more common than they were historically. This is true throughout the mixed-conifer forests, but especially so in lower montane communities. When fires burn through dense forests during hot, dry, windy conditions, they tend to burn in the tree crowns more often than they did when the forest structure was open. Crown fires kill more large trees than the frequent surface fires of the past. Nowadays, it is common to see large patches of *stand-replacing fires* in forests that used to experience stand-replacing fire in small, isolated patches.

High in the mountains of the Sierra Nevada are the subalpine forests, dominated by lodgepole pine, western white pine, mountain hemlock, and whitebark pine. This curriculum does not cover the high-elevation forests, but they are very important to the ecology of the Sierra Nevada and to the quality of life of its plants and wildlife, and to the human communities living in the watersheds below.

Table I-1—Summary of ecology and "fire story" of some forest communities of the Sierra Nevada

		Lower montane mixed conifer	Upper montane mixed conifer
Shade-intolerant tree species (grow well in sunny, open areas with bare soil)		Ponderosa pine Sugar pine California black oak	Jeffrey pine Sierra lodgepole pine
Shade-tolerant tree species (grow better than pine in shady places)		Douglas-fir White fir Incense-cedar	Red fir
Historical fire frequency	Crown fire	Infrequent, except in small patches	Infrequent, except in small to medium-sized patches
	Low-severity surface fire	4-14 per century	2-4 per century
Some animals		Mule deer Western gray squirrel Dusky-footed woodrat California spotted owl American black bear	Mule deer California spotted owl Yellow-legged frogs American black bear
Disturbances besides fire		Bark beetles White pine blister rust Drought	Bark beetles Drought

Design and Layout of Lessons in This Curriculum

Each activity has the following sections:

- **Lesson Overview**
- **Lesson Goal**
- **Objectives**
- **Teacher Background**
- **Materials and Preparation**
- **Procedure**
- **Assessment**
- **Evaluation**

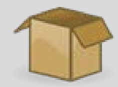
Subjects: Science, Writing, etc…

Duration:

Group size:

Setting:

FireWorks vocabulary (first introduced in to this activity):



Instructions for each activity also include a text box (example above) that lists subjects covered, the possible duration of the activity (a guess –take this with many grains of salt), group size, setting (laboratory, classroom, outdoors, etc.), and *FireWorks* vocabulary (list of terms in the *FireWorks Glossary* that are first introduced in this activity). The text box may also contain one or two icons – a red-and-white flame if the activity uses fire, and a brown box if the activity requires materials from a *FireWorks* trunk.

Handouts and other materials meant for students all begin with a large, bold-face header in **blue font**. Handout answer keys and other materials meant for teachers all begin with a large, bold-face header in **maroon font**. In the Procedures section and in handout answer keys for teachers, answers to questions are given in red font.

Links to Educational Standards

FireWorks need not compete with core curriculum for classroom time. Instead, it can help teachers cover core concepts and improve student skills by using hands-on materials based on science from their own local area. To help teachers identify the ways in which *FireWorks* can be used to meet their curriculum requirements, each activity is linked to educational standards.

FireWorks is correlated to the Common Core State Standards in English Language Arts (CCSS-ELA), Math (CCSS-Math), History and Social Studies, Science, and Technical Subjects; the Next Generation Science Standards (NGSS); the Excellence in Environmental Education: Guidelines for Learning standards (EEEGL); and the C3 Framework: College, Career and Civic Life for Social Studies State Standards (C3 SSSS)[1].

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[1] Abbreviations and links to standards:

- CCSS-ELA: Common Core State Standards—English Language Arts (http://www.corestandards.org/assets/CCSSI_ELA%20Standards.pdf)
- CCSS-Math: Common Core State Standards—Math (http://www.corestandards.org/wp-content/uploads/Math_Standards.pdf)
- NGSS: Next Generation Science Standards (http://www.nextgenscience.org/sites/ngss/files/NGSS%20DCI%20Combined%2011.6.13.pdf)
- EEEGL: Excellence in Environmental Education: Guidelines for Learning (http://resources.spaces3.com/89c197bf-e630-42b0-ad9a-91f0bc55c72d.pdf)
- C3 SSSS: College, Career and Civic life for Social Studies State Standards (http://www.socialstudies.org/system/files/c3/C3-Framework-for-Social-Studies.pdf)

Each lesson has been correlated to the relevant standards. If a lesson does not have standards listed from a particular standard framework, then it probably does not meet standards in that framework. However, teachers are encouraged to reinterpret standards and lessons and also to adapt lessons to meet their educational objectives and particular standards.

First, find the relevant grade(s).

Standards	Section	Sixth	Seventh	Eighth
Common Core ELA	Writing	4,10	4,10	4,10
	Speaking/Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Language Standards	1,2,3,6	1,2,3,6	1,2,3,6
	Reading Standards Science/Tech	4,7,9	4,7,9	4,7,9
	Writing Standards Science/Tech	4,7,10	4,7,10	4,7,10
NGSS	Structures/Properties of Matter	PS3.A		
	Energy	PS3.A		
	Waves/Electromagnetic Radiation	PS4.B		
EEEGL	Strand 1	A,C,E,F,G		

Second, find the relevant standards and access a copy of the respective publication.

Third, open standards publication to the appropriate grade and section.

Fourth, locate these numbers and read the associated standard.

Safety

Many of the experiments in this curriculum use fire and natural fuels in the classroom or laboratory. In these structured, well supervised environments, students can make discoveries about fire and improve their habits regarding fire safety. Help students learn about safe laboratory practices, such as using protective eyewear and wearing appropriate clothing. Help them learn that professional skills and years of experience are needed to use fire safely in wildlands. The following steps will help your students grow in responsibility and competence regarding lab safety and fire:

- Inform your maintenance staff about activities in which you will use fire.
- Inform your local fire protection unit if you plan to use fire outdoors.
- Consider informing parents about your plans and goals for teaching about fire.
- Choose your work space carefully, especially if you will not be using a laboratory. The fire engine must respond to every alarm, even if you tell them it's "only" an experiment.
- If you are working outdoors, watch carefully to prevent smoldering material from igniting schoolyard vegetation.
- Keep spray bottles filled with water. Have students use them to extinguish smoldering material at the end of each experiment. This will prevent trash-can fires.
- If you are working outdoors, keep a hose available and ready to use. Have a bucket or two of water available as well.

- Keep a fire extinguisher ready for use. Know how to use it. If you discharge a fire extinguisher, refill or replace it immediately. Don't burn anything without a charged fire extinguisher in the room.
- If you or any of your students have asthma or other respiratory problems, consider having them wear protective masks while working with fire.

Literature cited

American Association for the Advancement of Science. 1993. Benchmarks for science literacy. New York: Oxford University Press. 418 p.

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National Research Council. 1996. National science education standards. Washington, DC: National Academy Press. 262 p.

North American Association for Environmental Education. 1999. Excellence in EE—guidelines for learning (K-12). Rock Spring, GA: NAAEE Publications and Membership Office. 107 p.

Smith, Jane Kapler; McMurray, Nancy E. 2000. FireWorks curriculum featuring ponderosa, lodgepole, and whitebark pine forests. Gen. Tech. Rep. RMRS-GTR-65. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 270 p.

U.S. Department of Agriculture, Forest Service; Department of the Interior, Office of Wildland Fire Coordination. 2011. A national cohesive wildland fire management strategy. Washington, DC: Wildland Fire Leadership Council. 43 p.

This table summarizes the content for each activity at each grade level. Read across the table to find similar activities for students at other grade levels.

Unit & Theme	ELEMENTARY	MIDDLE	HIGH
Unit I. Introduction to Wildland Fire	E01. Visiting Wildland Fire in the Sierra Nevada	M01. Visiting Wildland Fire in the Sierra Nevada	H01. Introduction to Wildland Fire in the Sierra Nevada
Unit II. Physical Science of Wildland Fire	E02. Making Fires Burn or Go Out 1: Introduction to the Fire Triangle	M02. Where Does Heat Go? The Heat Plume from a Fire	H02. The Fire Triangle: Fuel, Heat, and Oxygen
	E03. Making Fires Burn or Go Out 2: Demonstrating the Fire Triangle and Heat Plume	M03. What Makes Fires Burn? The Fire Triangle 1—Heat and Fuel	H03. The Fire Triangle, Combustion, and the Carbon Cycle
		M04. What Makes Fires Burn? The Fire Triangle 2—Oxygen	H04. Heat Transfer
Unit III. The Wildland Fire Environment			H05. Fuel Properties
			H06. Pyrolysis
			H07. Fire Spread Processes: Putting it all together: Heat transfer, fuel properties, and pyrolysis
	E04. How Wildland Fires Spread 1: Experiment with a Matchstick Forest	M05. How Do Wildland Fires Spread? The Matchstick Forest Model	H08A. Fire Environment Triangle and Fire Spread: The Matchstick Model
			H08B. Fire Environment Triangle and Fire Spread: The Landscape Matchstick Model
		M06. Ladder Fuels and Fire Spread: The Tinker Tree Derby	H09. Ladder Fuels and Fire Spread
	E05. Fuel Properties: The Campfire Challenge	M07. Fuel Properties: The Campfire Challenge	See H05.
	E06. Effect of Wind: How Wildland Fires Spread	M08. Fire Behavior, Fire Weather, and Climate	H10. Fire Behavior, Fire Weather, and Climate

Unit IV. Fire Effects on the Environment	E07. Smoke from Wildland Fire: Just Hanging Around?	M09. Smoke from Wildland Fire: Just Hanging Around?	H11. Smoke from Wildland Fire: Just Hanging Around?
		M10. Fire, Soil, and Water Interactions	H12. Fire, Soil, and Water Interactions
Unit V. Fire's Relationship with Organisms and Communities	E08. Who Lives Here? Adopting a Plant, Animal, or Fungus	M11. Who Lives Here? Adopting a Plant, Animal, or Fungus	H14. Researching a Plant, Animal, or Fungus
	E09. Tree Parts and Fire: The Class Models a Living Tree	M12. Tree Parts and Fire: "Working Trees" Jeopardy-style Game	
	E10. Tree Identification: Using a Key to Identify "Mystery Trees"	M13. Tree Identification: Figure out the "Mystery Trees"	H13. Tree Identification: Create a Dichotomous Key
	E11. Recipe for a Baker Cypress Grove: Serotinous Cones		
		M14. Who Lives Here and Why? Modeling Forest Communities	H15. Forest Communities and Climate Change
		M15. Bark and Soil: Nature's Insulators	
	E12. Buried Treasure: Underground Parts that Help Plants Survive Fire	M16. Buried Treasures: Identifying Plants by their Underground Parts	
Unit VI. Fire History and Succession	E13-1. My Tree Autobiography: Seeing History through Trees' Growth Rings		
	E13-2. Story of a Fire-Scarred Tree	M17. Fire History 1: Long Stories Told By Old Trees	H16. Fire History 1: Long Stories Told by Old Trees
		M18. Fire History 2: History of Stand Replacing Fire	H17. Fire History 2: History of Stand Replacing Fire
	E14. Story Time: Fire and Succession	M19. Drama in the Forest: Fire and Succession, a Class Production	H18. Fire History 3: Fire Regime across a Sierra Nevada Landscape
Unit VII. People in Fire's Homeland	E15. Homes in the Forest: An Introduction to Firewise Practices	M20. Homes in the Forest: An Introduction to Firewise Practices	
	E16. Revisiting Wildland Fire	M21. Revisiting Wildland Fire	H19. Sierra Nevada Forests Today

Unit I.
Introduction to Wildland Fire

1. Visiting Wildland Fire in the Sierra Nevada

Subjects: Science, Writing, Speaking and Listening, Arts
Duration: one half-hour session
Group size: Whole class
Setting: Indoors
FireWorks vocabulary: *ecosystem, ecological community, fire behavior, wildland, wildland fire*

Lesson Overview: Students view a narrated photo presentation that shows wildland fires and some of the plants and animals they are going to learn about. The slides and narrative are at the end of the lesson and on a PowerPoint. During the presentation, students record observations about fire behavior. Afterwards, they compare and contrast the kinds of fire they observed, and they also describe their feelings about wildland fire. The presentation's narrative is brief because this activity is meant to orient the students and let them express their feelings about fire – not to teach science content.

Lesson Goal: Increase students' understanding that wildland fire is a complicated process that has complicated effects and may generate complicated feelings.

Objectives:
- Students can draw different kinds of fire behavior.
- Students can compare and contrast different kinds of fire behavior.
- Students can describe their feelings about wildland fire.

Standards:		6th	7th	8th
CCSS	Writing	4,10	4,0	4,10
	Speaking and Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Language	1,2,3,6	1,2,3,6	1,2,3,6
	Writing: Science and Technology	4,7,10	4,7,10	4,7,10
EEEGL	Strand 1	A,E,F,G		
NGSS	Human Impacts	ESS3.B,C		
	Weather and Climate	ESS2.D		
	Matter and Energy in Organisms and Ecosystems	LS2.C,B		
	History of Earth	ESS2.A		
	Interdependent Relationships in Ecosystems	LS2.C, LS2.A, LS4.D		
	Natural Selection and Adaptation	LS4.C		

Teacher Background: If you walk through a recently burned area, you might encounter some places where all the vegetation looks dead and other places that have a lot of green vegetation left. You might see deep holes in the ground where roots have burned away, and you might see patches of leaf litter that is just lightly scorched. Fire behavior and fire effects vary with topography, weather, and vegetation. As a result, some patterns are typical of certain kinds of landscapes and vegetation. For example, steep hillsides are more likely to support fast-moving fires than flatlands or moist ravines, and forests with trees close together are more likely to support crown fires (spreading through the tree canopy) than forests where the trees are far apart. As an introduction to the study of wildland fire, this photo presentation highlights variation in fire behavior and its relationship to specific plants and animals.

This version of FireWorks focuses on ecological communities in the Sierra Nevada– forests dominated by conifers. These communities are often called lower and upper mixed conifer or lower and upper montane. See the **Introduction** (pp. ii-iii) for an overview of these Sierra Nevada ecological communities.

If you plan to teach the units on fire ecology (V and VI), consider having your students adopt a plant, animal, or fungus NOW, so students have time to prepare and you can spread their presentations out over several days instead of having them all at once. See Activity 11, "Who Lives Here: Adopting a Plant, Animal, or Fungus" for further details.

Materials and preparation:

- Load photo presentation *E01_M01_VisitingWildlandFire.pptx*
- Copy Handout M01-1 for each student
- Write on the board: *species, ecosystem, ecological community*
- Flipchart or other media for recording questions, feelings

Procedure:

1. Explain to students: They will view a short presentation that shows fires in *wildlands*. In particular, they'll see different kinds of fire and different *ecological communities.* An ecological community includes all of the living things in an ecosystem – plants, animals, fungi, and microorganisms. An *ecosystem* includes the living things plus the nonliving parts of the ecosystem, such as soil, water, and air. Ask for examples of *community* members in your school. (Remember – only living things.) Ask for examples of the nonliving things in your school ecosystem. Ask which is more inclusive or "bigger" – community or ecosystem? (Ecosystem is bigger, because it includes the community and also nonliving things.)

2. Explain that you will stop four times during the presentation and ask them to record something by sketching what they observe. After the presentation, you will ask them to compare and contrast different kinds of *fire behavior* and also to describe their feelings about *wildland fire*.

3. Give out copies of Handout M01-1. Explain that you will let students know when you'd like them to use it to record observations.
4. Show the presentation. You can use the narrative in the presentation notes or give your own narrative, but keep it brief. Welcome students to discuss and ask questions about what they see. Record the questions on a flipchart or other medium, but don't necessarily try to answer them during the presentation. Instead, explain that the class will seek the answers during this unit on wildland fire and will come back to their questions in Lesson 21, "Revisiting Wildfire". Be sure to save the students' questions if you plan to do Lesson 21.
5. When you come to the four slides that show fire behavior and are cued to "*Observe and sketch*" – slides 1, 8, 14, and 21 – pause. Ask the students to look carefully at the flames in the photos—how long they are and what parts of the plants they are burning—and then record their observations by sketching the flames on their handout. They can also write a few words in the margin to describe the fire behavior. Give them a minute or more for each sketch.
6. After the presentation, have a brief discussion with the class about variety in fire behavior and also about their experiences with wildland fire and feelings about it. This discussion need not be long; it is a warm-up for the writing assignment.

Assessment:

Ask the students to write on the back of the handout or on a clean sheet of paper:

a. a paragraph in which they compare the kinds of fire they observed, giving at least two examples of how the kinds of fire are the same
b. a paragraph in which they contrast the kinds of fire, giving at least two examples of how the kinds of fire are different
c. a list of three words or phrases that describe their feelings about wildland fire. Explain that people's feelings often differ without being "right" or "wrong," so all of the feelings are valid. Also, since their feelings could change over time, they will have a chance to record their feelings again after they've learned more about fire.

Keep the flipchart or other media with students' questions and their handouts so they can be used again in Activity 21, at the end of this curriculum on wildland fire.

Evaluation:

	Good	Fair	Poor
a. Fire Comparison Paragraph	Complete paragraph. Contained two examples of similar fire behavior	Incomplete paragraph. Contained one example of similar fire behavior	Incomplete paragraph. Did not contain examples of similar fire behavior
b. Fire Contrast Paragraph	Complete paragraph. Contained two examples of different fire behavior	Incomplete paragraph. Contained one example of different fire behavior	Incomplete paragraph. Did not contain examples of different fire behavior
c. Fire Feelings List	Three words or phrases about personal feelings about wildland fire	Two words or phrases about personal feelings about wildland fire	One word or no words or phrase about personal feelings about wildland fire

Slides and Narrative for *E01_M01_VisitingWildlandFire.pptx*

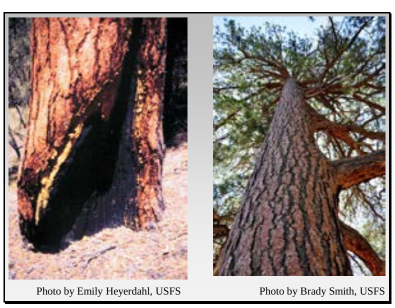
Slide 1

Here is a fire burning in a forest of the Sierra Nevada. *Observe and sketch it (A)*

Slide 2

This is what the land looks like after that kind of fire.

Slide 3



Here are some plants that live in the forest after fire:
… A ponderosa pine tree that has survived many fires

Slide 4

… Mariposa lily, a wildflower that survives fire and then grows really well.

Slide 5

… A California black oak that sprouts after fire.

Slide 6

Here are some animals that live in the forest after fire:
… Pileated woodpecker, which loves big, old trees that have survived fires long ago.

Slide 7

… Western gray squirrels that eat the seeds of trees that have survived the fire.

Slide 8

Here is another kind of fire in the Sierra Nevada. *Observe and sketch it (B).*

Slide 9

This is what the land looks like after that kind of fire.

Slide 10

Or this.

Slide 11

Here are some plants and animals that thrive after that kind of fire:
… A beetle with heat sensors, so it can find fires and lay its eggs in just-burned trees.

Slide 12

… A black-backed woodpecker, which arrives soon after the fire to eat the beetles.

Slide 13

… Deer brush, whose seeds germinate after fire cracks open its hard seedcoats.

Slide 14

Here is another kind of fire in the Sierra Nevada. *Observe and sketch it (C).*

This is a mixture of the two kinds of fire you've already observed. Many of those plants and animals can live here after fire.

Slide 15

Fire behavior and fire effects vary with topography, weather, and vegetation. Here are examples of fire behavior fires in the Sierra Nevada.

Slide 16

Slide 17

Slide 18

Slide 19

Slide 20

Slide 21

Fires in our forests can burn for a long time after the flames have passed. They may burn in tree trunks, roots, or in the soil itself.

Here is what a fire may look like after most of the flames have moved on (left photo). *Observe and sketch it (D).*

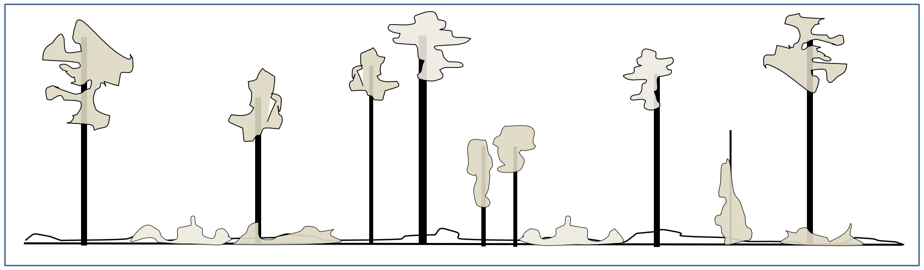
Wildland fires cause changes that last a long time, sometimes for hundreds of years. We'll learn more about all kinds of fire in the activities to come.

Handout M01-1: Fire Drawings.

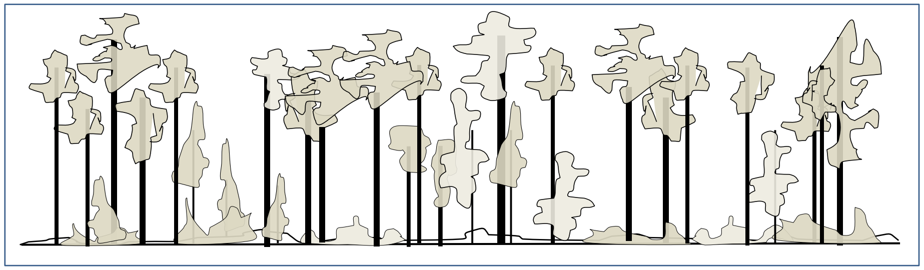
Name ______________________________

1. Color each sketch to show what part of the forest is burning (for example, soil, surface plants, or tree tops). Add a few words to describe fire behavior if you wish.

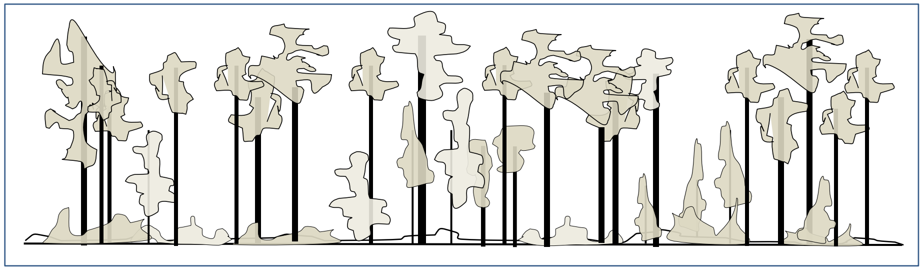
A.



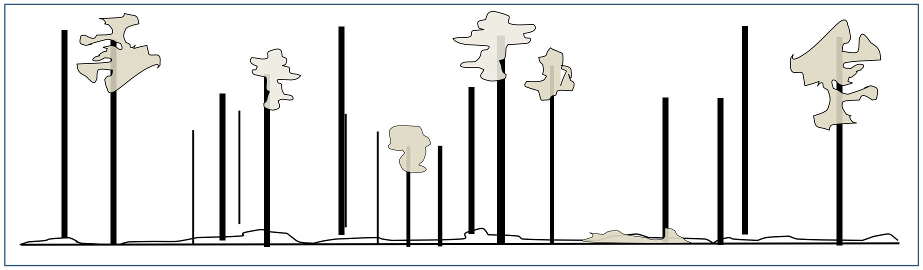
C.



B.



D.



Write:

1. One paragraph comparing the kinds of fire, giving at least two examples of how they are the same
2. One paragraph contrasting the kinds of fire behavior, giving at least two examples of how they are different
3. Three words or phrases that describe your feelings about wildland fire.

Unit II.
Physical Science of Wildland Fire

2. Where Does Heat Go?
The Heat Plume from a Fire

Lesson Overview: In this demonstration, students observe the heat from a burning candle and a single match so they can describe the shape and size of a heat plume and explain how the energy from a fire is transferred. Since this is the first activity in FireWorks to use actual fire, we suggest it as a demonstration so the class can go through and observe safety procedures together.

Lesson Goals: Increase students' understanding of heat dispersal from fires. Prepare students to safely conduct experiments with fire.

Subjects: Science, Mathematics, Writing, Speaking and Listening, Health and Safety

Duration: one half-hour session

Group size: Do as demonstration to whole class.

Setting: Laboratory or outdoors area sheltered from wind

New FireWorks vocabulary:
conduction, convection, heat plume, radiation

Objectives:

- Students can list three ways in which energy is transferred from a burning object.
- Students can describe the shape and size of a heat plume from a burning match.
- Students can list some safe practices for doing laboratory experiments with fire.

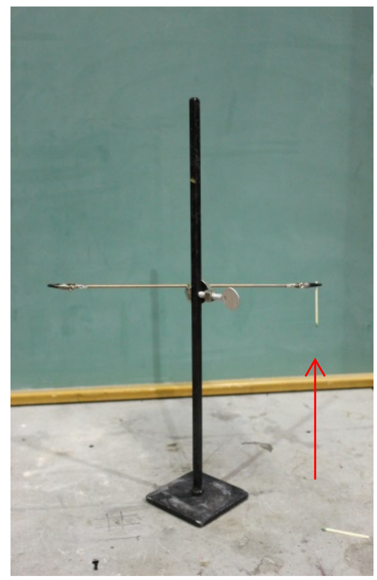
Standards		**6th**	**7th**	**8th**
CCSS	Writing	4,10	4,10	4,10
	Speaking and Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Language	1,2,3,6	1,2,3,6	1,2,3,6
	Writing: Science and Technology	4,7,10	4,7,10	4,7,10
NGSS	Structures and Property of Matter	PS3.A		
	Energy	PS3.A, B		
EEEGL	Strand 1	A,C,E,F,G		

Teacher Background: Most of the heat energy from a burning object usually disperses upward because the process of burning releases hot gases. The air at ground level is denser than that above because of gravity, so most of the hot, expanding gases of combustion tend to go upwards. The process in which warm gases and liquids generally move up, and cool ones move down is called *convection.* The heat plume from a fire does not always go straight up, however. A gust of wind, which can be thought of as a bubble of dense air, can push the hot gases sideways or even downward.

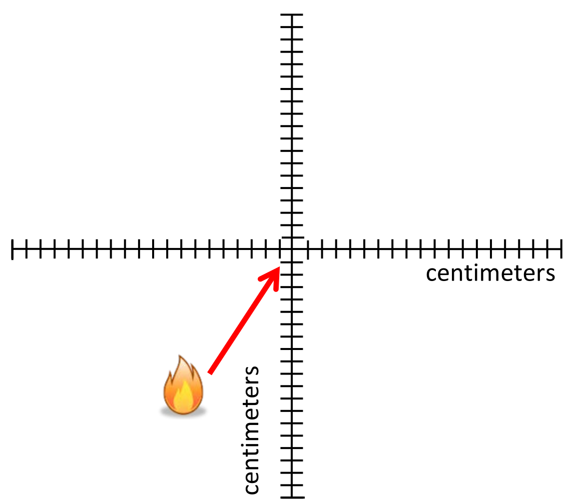
There are two other ways to transfer energy from a fire: *conduction* (the movement of energy from one atom or molecule to another in a solid) and *radiation* (the movement of energy through space by particles or waves). The demonstration in this activity explores all three means of heat transfer from a single burning match.

Materials and preparation:

Choose your location. This demonstration can produce flames 10-15 centimeters long. Can you do this safely in your classroom and without setting off a smoke alarm? Can you take your students to a lab where it will be safer? Do not try this demonstration outdoors because even the slightest wind will blow out a single match.



- Display the *FireWorks Safety* poster.
- Get a box of wooden kitchen matches.
- Fire extinguisher, fully charged
- Get a package of pre-wrapped hard candy. You'll need about twice as many pieces as you have students.
- Set up laboratory bench or other area to be used for demonstration with the following equipment (available in the trunk):
  - spray bottle, filled with water
  - ruler
  - metal tray (i.e., cookie sheet)
  - ashtray
  - votive candle
  - safety goggles
  - oven mitt
  - support stand
  - cross-piece for support stand. Has an alligator clip at each end.
  - clamp
- Set up the support stand with the clamp and cross-piece as illustrated above. Clip a match to one end with the ignitable tip pointing down.
- Draw the graph on the right on the board or project *M02_GraphForDescribingHeatPlume.pdf*:



Procedure:

PART ONE: Students demonstrate the 3 methods of heat transfer

1. Explain: In this activity, the class will work together to make observations about heat transfer from fires. As background, you need to know three terms: *convection, conduction,* and *radiation.* We'll set up a human demonstration to learn what they mean.
2. Have students stand side by side in a long line, shoulder to shoulder. Explain and do:
   a. *Conduction:* If they were atoms within a solid object, like a metal, they would move heat energy by passing it from one atom to another, each atom absorbing some and passing some on. (Pass the bag of candy to the first student, who takes a piece and passes it to the next, who does the same… all the way to the end of the line.)
   b. *Radiation:* Get the candy bag back (if there's any left!). Now pretend you are a source of light and heat, like the sun, *radiating* energy. You transfer that energy by sending out particles or waves through space. The energy travels until it contacts an atom or molecule, which it then heats up. (Throw a few pieces of candy directly to a few students.) *Radiation* explains how you can get a sunburn from energy that travels through space. Amazingly, the molecules of your skin are the first ones that sunlight touches in its 93-million-mile journey!
   c. *Convection* is the expansion of a bubble of hot gases into the cooler gases surrounding it. Gravity holds Earth's atmosphere to the ground, so the air becomes "thinner" (less dense) as you go up in altitude. Since "up" has less resistance to expanding gases than "sideways" or "down," hot air and the hot gases produced by combustion generally rise. Ask the class to imagine that their shoulder-to-shoulder line is vertical rather than horizontal. Pick 1-2 students to walk with you, arm-in-arm, from one end – the imaginary bottom of the heat plume – toward the other end, the imaginary top. Give a piece of candy to each student you pass – this means that your bubble of hot gases is losing heat as you go up, warming the surrounding air. If you run out of candy, stop. This means your bubble is the same temperature (i.e., has the same amount of energy per volume) as the air around you.
3. Have students take their seats for the next steps.

PART TWO: Students measure the shape of a heat plume

1. Explain: The class will work with the teacher to SAFELY measure the shape of a *heat plume* and learn how a fire can transfer heat through conduction, radiation, and convection.

2. Go through the FireWorks Safety poster with the class, checking your demonstration set-up to make sure all guidelines are met.

3. Demonstrate how to SAFELY light a match: Pull the match away from you, not toward you; hold it level or tilted slightly downward, not pointing directly downward; drop it into the ashtray or metal tray if it feels too hot. Always dispose of burned matches in the ashtray or on the metal tray.

> ## FireWorks Safety
>
> **When you do experiments with fire…**
>
> 1. **Wear cotton clothing. No synthetic pants, soccer shorts, etc.**
> 2. **Wear closed-toed shoes. No sandals or flipflops.**
> 3. **Tie back loose sleeves.**
> 4. **Tie back loose hair.**
> 5. **Make sure a fire extinguisher is close. Make sure it is charged. Know how to use it.**
> 6. **Make sure spray bottles are close and filled with water.**
> 7. **Wear safety goggles when burning.**
> 8. ***Never* lean over a fire.**
> 9. **Extinguish burned materials with water before putting them in the trash. *Fire is not out if there is any smoke or heat coming from the fuels.***
> 10. **If a fire starts on you, stop, drop, and roll.**
>
> **Use fire ONLY if a responsible adult is working with you.**

4. Get a volunteer from the class to be the Observer. Make sure he or she is dressed safely, following the poster guidelines.

5. Get another volunteer to be the Measurer and another to be the data Recorder.

6. Explain to the Observer: Your job is to find out how tall and wide the heat plume is from a burning match. You'll start by holding one hand about 40 centimeters to one side of the match. When the match is completely on fire, you'll bring your hand in closer until you can sense a change in temperature. The goal is to sense even a LITTLE warmth – NOT to see how close you can get without getting burned! We'll use as many matches as needed to get observations from two sides of the flame, above it, and below it. When you make the "below" observation, don't put your hand directly under the burning match, in case the tip breaks off and falls. Instead, hold your hand just a little to one side.

7. Explain to the Measurer: After each match is out, you'll measure the distance from its tip to the observer's hand (in centimeters).

8. Explain to the Recorder: You'll mark the correct axis of the graph to show each measurement.

9. Light the first match. As soon as it is completely on fire, obtain a "side" measurement and record it. After the match goes out, USE THE OVEN MITT to remove it from the clip, put a fresh one in, and get the opposite "side" measurement… a "below" measurement… then an "above" measurement. If you forget the oven mitt, you will quickly – and painfully – learn about conduction. Use as many matches as you need to get the 4 observations. Use the

same Observer for all 4 measurements. If you want to see variation from different observers, have another student or two repeat the observations, and then calculate an average for each dimension on the graph.

10. Have the Recorder connect the marks on the four axes, making a roughly oval shape.

11. Refer back to the three ways in which heat is transferred in a fire – conduction, convection, and radiation. Discuss/explain: The heat plume’s strong tendency to move upward demonstrates convection. Radiation sends energy in every direction; the heat you feel to the sides and beneath the flame is due to radiation. Conduction of heat is occurring from the fire into the metal clip, which is why you are using the oven mitt.

12. **Clean up:** Make sure all matches are our before you dispose of them – that is, until there is no smoke and no heat being released. Use a metal trash can without a plastic liner. If in doubt, dump the materials in a bucket of water before putting in the trash.

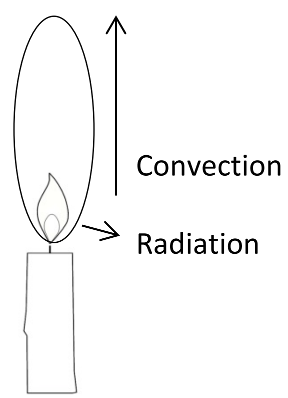
Assessment: Ask students to write/sketch answers to the following:

1. Where did the heat go? Use heat-transfer terms to describe the movement of heat upward, sideways, downward, and into the metal pieces?

2. Sketch a burning candle and show the shape of the heat plume. Label the diagram with words and arrows to show where convection and radiation are occurring.

3. Make a list of safety precautions that you should take when you get ready for school on days when fire experiments are scheduled. You can refer to the FireWorks Safety poster. Have students take the list home and post it in a place that they can refer to as they prepare for school.

Evaluation:

	Correct	**Incorrect**
1. Where did the heat go? Use vocabulary.	Most of the heat went upward through **convection,** the tendency of hot gases and liquids to rise. A little heat went in every direction through **radiation,** the process in which energy travels through space as particles or waves until it hits a molecule, which it heats up. Some heat went into the metal clip by **conduction** (the transfer of heat from particle to particle within a solid).	Student's descriptions did not reflect the correct use of the vocabulary term or a general understanding of the concept.
2. Burning Candle Diagram:		-Student does not have correct drawing of heat plume -Student does not show that convection moves heat upward. -Student does not show that radiation moves heat outward.
3. Fire Safety:	At least two fire safety rules, for example: -low-flammability clothing like cotton -no loose, floppy clothing -closed toed shoes -hair ties	Fewer than two safety rules were listed

3. What Makes Fires Burn?
The Fire Triangle 1—Heat and Fuel

Lesson Overview: In this activity and the next one, students learn about the concept of the Fire Triangle, then test it experimentally.

Lesson Goal: Increase students' understanding of fire as a process of chemical change.

Objectives:

- Students can describe the chemical change that occurs in combustion.
- Students can explain why combustion is a chemical change.

Subjects: Science, Health and Safety, Writing, Speaking and listening

Duration: One to two half-hour sessions

Group size: Whole class, working in teams of about 4 students

Setting: Indoors

New FireWorks vocabulary: *atom, carbon, carbon dioxide, chemical change, Fire Triangle, fuel, heat, hydrogen, model, oxygen*

Standards		6th	7th	8th
CCSS	Writing	4,10	4, 10	4, 10
	Speaking and Listening	1,4,5	1,4,5	1,4,5
	Language	1,2,3,6	1,2,3,6	1,2,3,6
	Writing: Science and Technology	3,9,10		
NGSS	Structures and Property of Matter	PS1.A, PS1B, PS3.A		
	Chemical Reactions	PS1.B		
	Energy	PS3.A		
EEEGL	Strand 1	A, C, E, F, G		

Teacher Background: This activity and the next one explore the chemistry of combustion as described by a conceptual model called the Fire Triangle. A fire cannot start without three things: fuel, oxygen, and a heat source. If a fire runs out of any of these things, it will stop. The three requirements for fire are conceptualized in the Fire Triangle. This is an appealing model because the geometric properties of the triangle are a good analog to the requirements for combustion: A triangle is very stable as long as all three legs are present (so stable, in fact, that it is used in the construction of buildings, furniture, and many other structures), and it collapses if one leg is removed. The triangle model is also appealing because it provides an easy way to introduce students to understanding a chemical change - the process of combustion. The three legs of the Fire Triangle actually represent the three inputs to the chemical equation for combustion, where H represents Hydrogen atoms, O represents Oxygen atoms, and C represents Carbon atoms:

Fuel + Oxygen + Heat $\longrightarrow$ Carbon dioxide + Water + Heat&Light

C&H atoms + O_2 + a little heat $\longrightarrow$ CO_2 + $6H_2O$ + Heat&Light

The equation above does not give a specific formula for fuels, because they could be any mixture of millions of compounds. The point is that all fuels contain a lot of carbon and hydrogen. They usually contain oxygen and many other kinds of atoms as well. For example, the equation for combustion of glucose, with numbers of molecules balanced to show conservation of matter, is this:

$$6CO_2 + 6H_2O + \text{Heat/Light} \longrightarrow C_6H_{12}O_6 + 6O_2$$

The same equation represents cellular respiration, the process by which cells convert sugar into the energy that keeps living things – including us – alive. Furthermore, this equation is the reverse of the chemical formula for photosynthesis! Thus the Fire Triangle can be used to introduce not only basic chemistry but also the basic principles of the biochemistry of life.

William Cottrell's *The Book of Fire* (2004, available from http://mountain-press.com/) is a well-illustrated, easy-to-read description of the physical science of combustion and wildland fire.

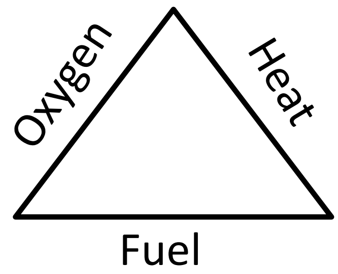
Handout M03-1: "Why Does the Match Go Out?" describes an experiment to demonstrate that both heat and fuel are essential for fire, and the heat must be able to reach the fuel for combustion to occur. In the next activity, students use an experiment to investigate the importance of oxygen in combustion, and they may also learn the difference between chemical change and phase change.

Materials and preparation:

Choose your location. If you burn in the classroom, be aware that this demonstration can produce flames 10-20 centimeters long. Can you do this safely in your classroom and without setting off a smoke alarm? Can you take your students to a lab where it will be safe? Do not try to burn outdoors because even the slightest wind will blow out single matches and candles.

- The day before doing this activity, remind students to follow the safety guidelines about clothing and hair when they get ready for school tomorrow.
- Get a package of hair bands to keep in your pocket so you can give them out as needed.
- Get four boxes of kitchen matches. The boxes need not be full.

- Draw the Fire Triangle on the board, labeling the sides. Make it big enough that you can add information next to and below it during class discussion:

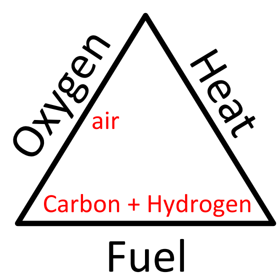


- Set up the teacher's lab bench with this equipment (mostly available in trunk):
  - Two spray bottles, filled with water
  - Fire extinguisher, fully charged
  - A votive candle
  - A box of matches
- Set up a lab bench or other safe space for each student team with the following equipment:
  - 1 ruler
  - 1 metal tray (i.e., cookie sheet)
  - 1 ashtray
  - 1 box of matches
  - 1 pair safety goggles
  - 1 oven mitt
  - 1 support stand with cross-piece attached by clamp (see photo, at right)

- Have a *metal* trash can or bucket *without a plastic liner* available.
- Make 1 copy/student of **Handout M03-1**: Why Does the Match Go Out

Procedure:

1. Explain: The *Fire Triangle* is one way to understand what makes fires burn and what makes them go out. It is a *model* – something that helps us understand a process and make predictions about it. In the last activity we made a <u>physical</u> model to demonstrate heat transfer (conduction, convection, and radiation). The Fire Triangle is a <u>conceptual</u> model. Let's briefly review and discuss the Fire Triangle. Then we'll test it experimentally.



2. Ask students to name some *fuels*. List them on the board below the "Fuels" label on the Fire Triangle. Don't limit the list to wildland fuels; for example, gasoline, birthday candles, and coal can be included. When the list is fairly long, ask <u>which fuels occur in wildland fires</u> and underline them. Explain that all fuels are made up of many kinds of *atoms* all stuck together – especially *carbon* and *hydrogen* atoms. Inside the Fire Triangle and parallel to the "Fuels" label, write these element names. (You can add that fuels can contain dozens of other kinds of atoms, but carbon and hydrogen are the ones that are essential for combustion.)

3. Point out that, according to the list of fuels, burnable things surround us every day. Why aren't they on fire? (There is not enough *heat* available to *ignite* them.) Ask students to name some heat sources for fire, and list them on the board next to the "Heat" label. Again, don't limit the list to ignition sources for wildland fire; for example, spark plugs and static electricity can be included. Underline the <u>heat sources that can start wildland fires without human help</u> (lightning and volcanic activity).

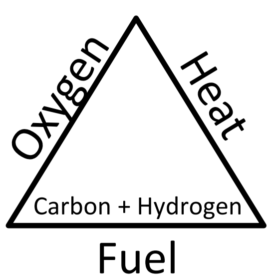
4. Ask where the *oxygen* for fires comes from. It is, of course, from air; oxygen comprises about 21% of the air we breathe. Write "air" next to the "Oxygen" label on the Triangle. (By the way, we use only about 20 % of air's oxygen in a single breath. If we used all of it, cardiopulmonary respiration (CPR) wouldn't work!)

5. **Do a safety briefing** in preparation for handling matches in these experiments. Demonstrate a safe way to light a match—that is, hold it level or pointing slightly down, strike away from you, and work over a noncombustible surface so you can drop it quickly but safely even if it is still burning. Review the location of spray bottles and fire extinguisher.

6. Give each student or team a copy of Handout M03-1, and tell them to follow the instructions on the handout. If they record multiple observations for (A) and (B), you may ask them to calculate means and medians. As a class, discuss their answers. In regard to (C):

   - The downward-pointing match probably burned almost completely. The fire went out mainly because it ran out of fuel. If a tiny stub of unburned wood remained in the alligator clip, it didn't burn because the clip absorbed much of the heat and limited the oxygen that could get to the fuel.
   - The upward-pointing match probably went out before it burned completely, so it could not have been limited by fuel. Students may guess that it was limited by oxygen. You can respond to this by asking if they have any indication that the air around them is short of oxygen – were they having trouble breathing? The explanation lies in the relationship between heat and fuel: Most of the heat was moving up, away from the fuel, as they learned in Activity M02. If any heat was going down, it was not sufficient to keep the wood burning.

7. Below the Fire Triangle on the board, add the following line, which summarizes the *chemical changes* that occur during combustion. "C," "H," and "O" are abbreviations for the three kinds of *atoms* in this process.



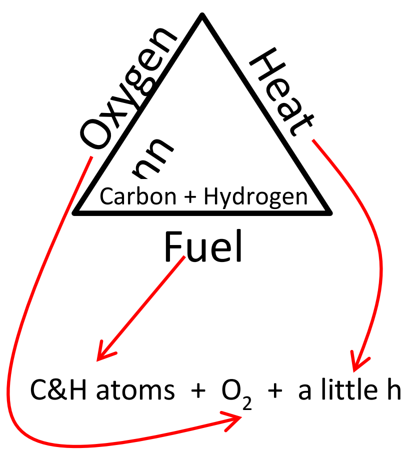
C&H atoms + O_2 + a little heat ⟶ carbon dioxide (CO_2) + water (H_2O) + lots of heat & light

Show and explain:

- The carbon and hydrogen atoms (C&H) in fuels provide the first ingredient for combustion, oxygen (O_2) is the second ingredient, and heat is the third "ingredient."
- Exactly the same kinds of atoms are present in the products of combustion (*carbon dioxide* and water), <u>but they have been recombined</u>. It is that rearrangement of atoms that produces so much heat and light.
- Combustion is a *chemical change,* a rearrangement of atoms that changes substances from one kind to another.
- Most chemical changes are hard to reverse. For example, baking a cake causes chemical changes – and it is very hard to turn a cake back into its original ingredients! In combustion, fuels and pure oxygen are changed into carbon dioxide and water, and the change produces heat and light.
- Plants are the only thing on earth that can easily reverse the combustion reaction. Photosynthesis combines carbon dioxide with water to form carbohydrates (comprised, as the name implies, mainly of carbon and hydrogen).

Assessment: Ask students to copy the Fire Triangle diagram and the chemical equation for combustion onto a piece of paper. On the paper, have them:

1. Draw an arrow from each leg of the Fire Triangle to each ingredient in the chemical formula for combustion.
2. Explain in writing why combustion is a *chemical change*.



C&H atoms + O_2 + a little heat $\longrightarrow$ carbon dioxide (CO_2) + water (H_2O) + lots of heat & light

Evaluation:	Correct	Incorrect
1. Connect the Fire Triangle with the combustion equation	Student drew three lines from the three legs of the Fire Triangle to the appropriate parts of the combustion equation.	Student did not draw three lines correctly from Fire Triangle to the appropriate parts of the combustion equation.
2. Combustion as chemical change	Combustion is a chemical change because the atoms in the fuels and oxygen are broken apart and then recombined to form new substances – carbon dioxide and water.	Student did not communicate in writing an understanding of combustion as a chemical change.

Handout M03-1: Why Does the Match Go Out?

Name: ___________________________

Organize your team. Change jobs if you repeat the experiment. On a team of 4:

- The **Observer** should light the matches.
- The **Timer** should measure the duration of burning (in seconds).
- The **Measurer** should measure the length of flames.
- The **Recorder** should record data.

Steps:

1. Place the metal tray on a heat-resistant surface. Set the support stand in the center of the metal tray. Attach the clamp to the stand. Attach the cross-piece with alligator clips to the clamp, so it forms a "+" with the stand.
2. Clip a wooden match to each alligator clip. Attach one match so the ignitable tip points straight up. Attach the other so the ignitable tip points down.
3. Light a third match and use it to ignite the downward-pointing match. Record your observations (A and B in first column below). Always dispose of burned matches in the ashtray or on the metal tray.
4. Use another match to ignite the upward-pointing match. Record your observations (A and B in second column below).
5. You may repeat the experiment to get more observations. <u>If you do, use the oven mitt</u> to <u>handle the alligator clips</u>. If you forget, you will quickly learn about *conduction.*
6. Answer question C for the downward-pointing match, then for the upward-pointing match.
7. **Clean up:** Make sure all burned materials and matches are our before you dispose of them – that is, there is no smoke and no heat being released. Use a metal trash can without a plastic liner. If in doubt, dump them in a bucket of water before putting them in the trash.

Match is pointing…	**Down**	**Up**
A. With the ruler near the flame <u>but not in it</u>, measure the flame length (centimeters). Record up to 3 observations.		
B. How long did the match burn (seconds)? Record up to 3 observations.		
C. Use the Fire Triangle to explain why the match went out.		

4. What Makes Fires Burn?
The Fire Triangle 2—Oxygen

Lesson Overview: In this activity, students learn more about the Fire Triangle and further test it experimentally. **We describe 2 options for doing the experiment: Option 1 uses vinegar and baking soda; Option 2 uses dry ice.**

Lesson Goal: Increase students' understanding of combustion and the Fire Triangle model.

Objective: Students can use the Fire Triangle to explain why various techniques work to stop fires

Subjects: Science, Health and Safety, Writing, Speaking and listening

Duration: One half-hour session

Group size: Whole class, working in teams of about 4 students each

Setting: Indoors

New FireWorks vocabulary: *molecule. If you use Option 2 with dry ice, additional vocabulary: phase change, sublime/sublimation*

Standards		6th	7th	8th
Common Core ELA	Writing	1,4,7,10	1,4,7,20	1,4,7,10
	Speaking/Listening	1,2,5	1,2,5	1,2,5
	Language Standards	1,2,3,6	1,2,3,6	1,2,3,6
	Reading Standards Science/Tech	9	9	9
	Writing Standards Science/Tech	2	2	2
NGSS	Structures and Property of Matter	PS3.A, PS1.A, PS1.B		
	Chemical Reactions	ETS1.B		
	Energy	ETS1.B		
	Engineering Design	ETS1.A, ETS2.B, ETS1.C		
EEEGL	Strand 1	A, B, C, E, F, G		

Teacher Background -- Initial background is in the previous activity (M03). Here is more: The 2 options for experiments in this activity (Handout M04-1 and M04-02) demonstrate that oxygen is required for fire. Both options use carbon dioxide gas.

- In Option 1, the gas is produced by combining baking soda and vinegar; if you use this option, you can explore the chemical reactions between baking soda and vinegar.

- In Option 2, the gas is produced from dry ice; if you use this option, you can explore the difference between phase change and chemical change.

About carbon dioxide gas: Carbon dioxide is one of the components of air. It is heavier than oxygen, as you can see from this calculation of the molecular weights of the two compounds:

Element	Atomic weight
Carbon (C)	12 g
Oxygen (O)	16 g

A mole of CO_2 weighs 12 g + 2 * 16 g = 44 g

A mole of O_2 weighs 2 * 16 g = 32 g

Thus, if carbon dioxide and oxygen are placed together in a container with no turbulence, the carbon dioxide will sink to the bottom and the oxygen will rise to the top.

Option 1 background: These 2 equations describe the chemical changes that produce carbon dioxide gas from vinegar and baking soda:

[1]	vinegar	+	baking soda	→	carbonic acid	sodium acetate
	(acetic acid)		(sodium bicarbonate)			
	CH_3COOH	+	$NaHCO_3$	→	$H_2CO_3(aq)$	$NaCH_3COO$ (aq)

Sodium acetate is the goo at the bottom of the container. Carbonic acid looks like water. The carbonic acid immediately breaks down into carbon dioxide gas and water:

[2] $H_2CO_3 \rightarrow CO_2(g) + H_2O$

Option 2 background: When a substance changes from one phase (solid, liquid, gas) to another, it undergoes a phase change. This is different from a chemical change. As described in the previous activity, in a chemical change the molecules in the ingredients are broken into their component atoms, and the atoms are recombined to form new molecules; the change cannot be reversed easily. In a phase change, the atoms in the ingredients are not recombined, and the change can be reversed fairly easily.

When you use dry ice for this experiment, you convert frozen carbon dioxide from the solid phase, at a temperature of −78.5 °C (−109.3 °F) or lower, into its gaseous phase. Note that carbon dioxide does not form a liquid at Earth's atmospheric pressure, so it goes directly from the solid phase to the gas phase – hence the term "dry" ice. We say that the dry ice "sublimes," and the process is called "sublimation."

Option 1: Experiment using vinegar and baking soda

Materials and preparation:
Choose your location. You will be burning individual votive candles. Can you do this safely in your classroom and without setting off a smoke alarm? Can you take your students to a lab where it will be safe? Do not try to burn outdoors because even the slightest wind will blow out the candles.

- The day before doing this activity, remind students to follow the safety guidelines about clothing and hair when they get ready for school tomorrow.
- Get a package of hair bands to keep in your pocket so you can give them out as needed.
- Get 4 boxes of wooden kitchen matches. The boxes need not be full.
- Get 1 box of long fireplace matches.
- Set up the teacher's lab bench with this equipment:
    - Fire extinguisher, fully charged
    - Two spray bottles, filled with water
- Set up a lab bench or other safe space for each student team[1], using the following equipment:
    - 1 metal tray (i.e., cookie sheet)
    - 1 ashtray
    - 1 box of matches
    - 2 votive candles
    - 2 beakers or freezer containers
    - 1 pair safety goggles
    - 1 oven mitt
    - 1 long fireplace matches (Students can re-light these and use them repeatedly rather than using a new match for every iteration of the experiment.)
- If possible, have a *metal* trash can *without a plastic liner* available.
- Print **Handout M04-1** for each student.

Procedure:

1. Explain: In the last activity, we saw that both fuel and heat are essential for fire to occur, but we didn't really look at the role of oxygen. That's that we'll explore in this experiment.

2. Review the "Oxygen" part of the Fire Triangle: It comprises about 21% of the air we breathe, and we use only about 20 % of that oxygen in a single breath. If we used it all in breathing, we couldn't use cardiopulmonary resuscitation (CPR) to help a person who is not breathing.

3. As a review, ask students to describe the nature of a *chemical change* (a rearrangement of atoms that changes substances from one kind to another, producing a different kind of molecule).

[1] The trunk is supplied with 4 sets of equipment.

4. Explain: You will combine vinegar and baking soda in a chemical reaction that produces carbon dioxide. When vinegar and baking soda are combined, they produce carbonic acid and sodium acetate. The carbonic acid breaks down into carbon dioxide and water. You may want to share the chemistry below.

	vinegar (acetic acid)	+	baking soda (sodium bicarbonate)	→	carbonic acid	sodium acetate
[1]	CH_3COOH	+	$NaHCO_3$	→	$H_2CO_3(aq)$	$NaCH_3COO\ (aq)$

Sodium acetate is the goo at the bottom of the container. Carbonic acid looks like water. The carbonic acid immediately breaks down into carbon dioxide gas and water:

[2] $H_2CO_3 \rightarrow CO_2(g) + H_2O$

5. Do a **safety checkup** with students using the *FireWorks Safety* poster.

6. Give each student or team a copy of **Handout M04-1**. Have students go over the instructions. Answer questions. Then give out materials and have them conduct the experiment.

7. After students have finished, discuss their responses to A-D in the table on the handout. Soon after vinegar has been added to the baking soda in the container, they should find it impossible to light the candle. Carbon dioxide has filled the bottom of the container. It is heavier than oxygen, so it doesn't rise and mix with the surrounding air. Instead, it crowds the oxygen out. Without oxygen, the candle won't burn.

8. Now ask students to apply what they have learned: Ask them to name some techniques for putting fires out. List these on the board. Select <u>one</u> of them. In a discussion, get students to use concepts from the Fire Triangle to explain why the technique works. Then erase this technique from list, leaving the rest for the Assessment.

Assessment: Select one of the techniques listed on the board for putting fires out.

a. Write down the technique you've chosen.
b. Use one or more components of the Fire Triangle to explain why the technique works. In your explanation, use at least one sentence and terms from the Fire Triangle.

Evaluation:

-Student named the technique chosen. -Explanation was logical. -Used 1 or more term(s) from Fire Triangle.	-Student named the technique chosen. -Explanation was logical. -Did not use term(s) from Fire Triangle.	-Student did not name a technique. -Explanation was illogical. -Did not reference Fire Triangle.

Handout M04-1. Why does the candle go out?

Name: ______________________________

1. Place one votive candle on the metal tray and light it. You will light matches from this candle.
2. Place the other candle in a beaker or other container.
3. Light the long fireplace match from the burning candle on the metal tray. Then use it to light the candle in the container. If either candle is hard to light, you may need to scrape some wax from around the wick. This step proves that the candle in the container can be lighted.
4. Blow out the candle in the container.
5. Spoon 1-2 tablespoons of baking soda around the base of the candle, about enough to coat the bottom of the container. Be careful not to get the baking soda on the candle. Alternative: Add the baking soda to an empty container and then replace the candle.
6. Light the candle to make sure that the baking soda did not alter its ability to burn. Then blow it out.
7. Pour about ¼ c (60 mL) of vinegar into the baking soda around the candle. Do this slowly so the mixture doesn't foam so enthusiastically that it wets the candle wick.
8. Relight the fireplace match from the candle on the metal tray. Then use it to relight the candle in the container.
9. Try different techniques for lighting the candle in the container.
10. Use complete sentences to answer the questions below.

A. Describe what you observed when you mixed vinegar and baking soda.
B. Describe what you observed when you were lighting the candle in the container after vinegar was added.
C. Describe any other techniques you used to light the candle in the container, and explain how well each technique worked.
D. Use the Fire Triangle to explain your observations.

Handout M04-1 Answer Key. Why does the candle go out?

A.	Describe what you observed when you mixed vinegar and baking soda. The mixture foamed. Then a white substance accumulated at the bottom of the container, and it was covered by a clear liquid.
B.	Describe what you observed when you were lighting the candle in the container after vinegar was added. It was impossible to light… unless the air in the room was turbulent or someone blew into the container.
C.	Describe any techniques you used to light the candle in the container, and explain how well each technique worked. This is a fun part of the experiment. Students may try moving more quickly; this won't work. They may try tipping the container sideways; this may work because you are pouring some of the carbon dioxide out. They may also try taking the candle out and pouring the carbon dioxide onto the lighted candle on the tray; that will probably extinguish the flame.
D.	Use the Fire Triangle to explain your observations. Carbon dioxide is heavier than oxygen, so it stays in the container while the oxygen is pushed out. Without oxygen, the candle cannot be lit.

Option 2: Experiment using dry ice

Materials and preparation:
Choose your location. You will be burning individual votive candles. Can you do this safely in your classroom and without setting off a smoke alarm? Can you take your students to a lab where it will be safe? Do not try to burn outdoors because even the slightest wind will blow out the candles.

- The day before doing this activity, remind students to follow the safety guidelines about clothing and hair when they get ready for school tomorrow.
- Get a package of hair bands to keep in your pocket so you can give them out as needed.
- Get 4 boxes of wooden kitchen matches. The boxes need not be full.
- Get 1 box of long fireplace matches.
- Set up the teacher's lab bench with this equipment:
  - Fire extinguisher, fully charged
  - Two spray bottles, filled with water
  - Tongs for handling dry ice
- The morning of the experiment, get 2-3 pounds of dry ice from a local supermarket. Store it in a cooler or freezer until class time. Find a hammer or something else for crushing the dry ice.
- Set up a lab bench or other safe space for each student team[2], using the following equipment:
  - 1 metal tray (i.e., cookie sheet)
  - 1 ashtray
  - 1 box of matches
  - 2 votive candles
  - 2 beakers or freezer containers
  - 1 pair safety goggles
  - 1 oven mitt
  - 1 long fireplace matches (Students can re-light these and use them repeatedly rather than using a new match for every iteration of the experiment.)
- If possible, have a *metal* trash can *without a plastic liner* available.
- Print **Handout M04-2** for each student.

Procedure:

1. Explain: In the last activity, we saw that both fuel and heat are essential for fire to occur, but we didn't really look at the role of oxygen. That's that we'll explore in this experiment.

2. Review the "Oxygen" part of the Fire Triangle: It comprises about 21% of the air we breathe, and we use only about 20 % of that oxygen in a single breath. If we used it all in breathing, we couldn't use cardiopulmonary resuscitation (CPR) to help a person who is not breathing.

---

[2] The trunk is supplied with 4 sets of equipment.

3. Review: Ask students to describe the nature of a *chemical change* (a rearrangement of atoms that changes substances from one kind to another, which produces a different kind of molecule).

4. Explain: As dry ice changes from the solid phase to the gas phase, the atoms are <u>not</u> rearranged and a different kind of molecule is <u>not</u> produced. The process of *subliming* dry ice is a *phase change* as opposed to a *chemical change.* Other familiar phase changes are the melting of "regular" ice into water and the evaporation of liquid water into water vapor. Phase changes are usually easy to reverse if you add or remove heat. For example, we can thaw ice (change from solid to liquid) and easily refreeze the liquid water back to ice again. In contrast, consider how hard it would be to un-bake a cake!

5. **Do a safety checkup** with students using the *FireWorks Safety* poster.

6. **More about safety - Explain: You'll be using "dry ice."** This is frozen carbon dioxide, and it's very cold (−78.5 °C (−109.3 °F)) – much colder than ice made from water. Because it is so cold, it should never be handled without tongs or gloves or a thick oven mitt. If you leave dry ice in a container for a while, it will disappear because the solid carbon dioxide is *subliming*—going from the solid phase to the gas phase without a liquid phase in between. Gaseous carbon dioxide is invisible and comprises about 1% of air.

7. Give each student or team a copy of **Handout M04-2**. Have students go over the instructions. Explain that you will provide them with dry ice when they have finished the first 4 steps in the experiment. Answer questions. Then give out materials and have them conduct the experiment. When each team is ready for dry ice, use the tongs to place a few pieces in their candle container. (The volume of about 2-3 ice cubes should do.)

8. After students have finished, discuss their responses to A-C in the table on the handout. Soon after the dry ice has been added to the container, they should feel the cold around the container and it should be impossible to light the candle inside. They may also observe fog in the container. This is not gaseous carbon dioxide. (Remember, that is invisible.) Instead, it is water vapor condensing out of the room's air because the gas in the container is so cold. Carbon dioxide has filled the bottom of the container. It is heavier than oxygen (and it is cold so it is much dense than room-temperature), so it doesn't rise and mix with the surrounding air. Instead, it crowds the oxygen out. Without oxygen, the candle won't burn.

9. Now ask students to apply what they have learned: Ask them to name some techniques for putting fires out. List these on the board. Select <u>one</u> of them. In a discussion, get students to use concepts from the Fire Triangle to explain why the technique works. Then erase this technique from list, leaving the rest for the Assessment.

10. Use the Assessment and Evaluation from Option 1 above.

Handout M04-2: Why does the candle go out?

Name: ________________________

1. Place one votive candle on the metal tray and light it. You will light matches from this candle.

2. Place the other candle in a beaker or other container.

3. Light the long fireplace match from the burning candle on the metal tray. Then use it to light the candle in the container. If either candle is hard to light, you may need to scrape some wax from around the wick. This step proves that the candle in the container can be lighted.

4. Blow out the candle in the container.

5. Ask the teacher to place some pieces of dry ice next to the candle in the container. <u>If you need to handle the dry ice, use the oven mitt.</u>

6. Relight the fireplace match from the candle on the metal tray. Then use it to relight the candle in the container.

7. You may repeat the experiment and use different techniques to light the candle in the container.

8. Answer the questions below.

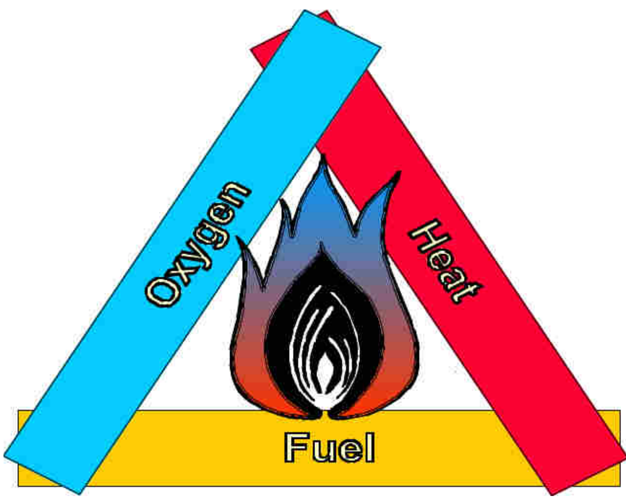
A. Describe what you observed when you were relighting the candle in the container.
B. Describe techniques you used to try to light the candle in the container. Explain how well each technique worked.
C. Use the Fire Triangle to explain your observations.

Handout M04-2 Answer Key. Why does the candle go out?

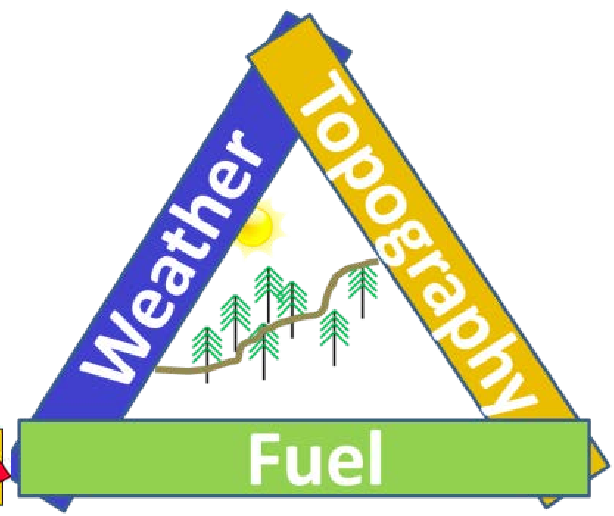
A. Describe what you observed when you were relighting the candle in the container. The container was cold. It may have had fog inside. It was impossible to light the candle… unless the air in the room was turbulent or someone blew into the container.
B. Describe techniques you used to try to light the candle in the container. Explain how well each technique worked. This is a fun part of the experiment. Students may try moving more quickly; this won't work. They may try tipping the container sideways; this may work because you are pouring some of the carbon dioxide out. They may also try taking the candle out and pouring the carbon dioxide onto the lighted candle on the tray; that will probably extinguish the flame.
C. Use the Fire Triangle to explain your observations. Carbon dioxide is heavier than oxygen, so it stays in the container while the oxygen is pushed out. In addition, carbon dioxide gas that has just sublimed from dry ice is very cold, so it is much denser than it would be at room temperature – again, staying put in the container while oxygen is pushed out. Without oxygen, the candle cannot be lit. Students may think that it is too cold inside the container to light the candle, so the "heat" component of the Fire Triangle is missing. That is unlikely, but this experiment doesn't provide a good way to test the hypothesis. Perhaps they can come up with an experiment to do so!

Unit III.
The Wildland Fire Environment

Now that students understand the basic principles of combustion as described by the Fire Triangle, they will apply that understanding to how fires behave in wildlands. Fire professionals use a second triangle model, the Fire Behavior Triangle, to describe the complexities of wildland fire behavior. Each activity in this section addresses some features of the Fire Behavior Triangle.



Fire Triangle



Fire Behavior Triangle

5. How Do Wildland Fires Spread? The Matchstick Forest Model

Lesson Overview: In this activity, students use a physical model to learn how slope and the density of trees (or other kinds of standing fuels) affect fire spread.

Lesson Goal: Increase students' understanding of wildland fire spread in forests and other kinds of standing fuels.

Objectives:

- Students plan experiments and make observations to investigate the effect of one variable at a time on fire spread.
- Students use the Fire Triangle (from Unit II) to explain how slope and density of trees (or other standing fuels) affect fire spread.

Subjects: Science, Mathematics, Health and Safety, Writing, Speaking and Listening

Duration: Two to three half-hour sessions

Group size: Whole class, working in 4 teams to prepare demonstrations

Setting: Indoor laboratory or outdoors

New FireWorks vocabulary: *backing fire, crown fire, density/stand density, experimental variable, ground fire, head fire, slope, stand, standing fuels, surface fire, topography*

Standards:		**6th**	**7th**	**8th**
CCSS	Writing	4,10	4,10	4,10
	Speaking and Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Language	1,2,3,4,6	1,2,3,4,6	1,2,3,4,6
	Writing: Science and Technology	2	2	2
NGSS	Structures and Property of Matter	PS3.A		
	Energy	ETS1.B, ETS1.B		
	Human Impacts	ESS3.C		
	Weather and Climate	ESS2.D		
	History of Earth	ESS2.A		
	Engineering Design	ETS1.A, ETS2.B, ETS1.C		
EEEGL	Strand 1	A,B,C,E,F,G		

Teacher Background: Now that students understand the basic principles of combustion as described by the Fire Triangle, they will apply that understanding to how fires behave in wildlands. In this activity, they will use a physical model called the "matchstick forest" to investigate two of sides of the Fire Environment Triangle (also called Fire Behavior Triangle):

- slope (a feature of *topography*)
- the *density of trees or other standing fuels*

In the matchstick forest model, standing fuels are represented by single matches. For safety's sake, it is important to note that the flames in this experiment can reach a foot or more in height. Plan accordingly. If you do the burning outdoors, even the slightest breeze will dramatically affect fire spread. In this case, the experiments may illustrate mainly that fire spread is complex and often unpredictable. You can investigate the effects of wind on fire behavior in Activity 8.

The activity consists of 2 experiment sets. Experiment Set 1 investigates the effect of slope on fire behavior. We suggest you discuss the experimental design, hypotheses, and measurements as a class while you do Set 1, to prepare students for doing the same thing on their own in Experiment Set 2. Set 2 investigates the effect of *stand density* (the spatial arrangement of trees or other standing fuels).

While the activity is especially well suited to studying tree density, the principles apply to any vertical fuel array – tall shrubs or grasses, for example. Here are explanations for the fire behavior that you may see in the experiments:

> Experiment 1. If a fire is burning on a hillside, the fuels above it tend to be dried and warmed by its convective heat and the flames are quite close to these fuels, while the fuels below are affected very little – at least until burning materials roll downhill and ignite new fires below. Thus fires tend to spread upslope, and a fire that starts at the bottom of a hill is likely to spread faster than one that starts on a hilltop.
>
> Experiment 2. If a fire is burning in dense forest, it may spread from treetop to treetop (*crown fire*). In more open forests, crown fires are less likely. Here is a caveat, however: Surface fires may spread more rapidly in open than dense stands because the wind speed is usually greater in openings.

Table M05-1: describes the experiments included in this activity. Use Experiment Set 1 to learn about the effect of slope. Then use <u>either</u> Experiment Set 2A <u>or</u> 2B to learn about the effect of stand density. Student's directions for each experiment set, which you can project as needed, are in *M05_MatchstickForestExperimentDesigns.pptx.*

- Use Experiment Set 2A if you want students to learn about stand density as it applies to ALL kinds of plant communities subject to fire (ANY kind of forest, woodland, shrubland, or even grassland, the world over).
- Use Experiment Set 2B if you want students to learn about stand density as it applies to specific kinds of fire histories in your geographic area.

Table M05-1: Experiments for investigating the effect of slope and density of standing fuels on fire spread.

Experiment Set & Experimental Question	Potential hypotheses & explanations	Experimental setup
Experiment Set 1. How does slope affect fire spread?	Fires moving uphill tend to spread faster and burn more completely than fires moving downhill. **Explanation:** As heat moves upward by convection, it dries and heats the fuels above. In addition, flames are closer to uphill fuels than to those on level ground or downslope.	Use 4 boards (4 experiments). Use 49 matches/board. Lay 1 board flat. Use short bolts to model 2 forests on moderate slopes. Use a long bolt to model a forest on a steep slope. Ignite an entire row of matches along the edge of each board: • On flat board, ignite one side. • On 1 moderately steep board, ignite from the top row (*backing fire*) • On the other moderately steep board, ignite from the bottom row (*head fire*). • On steep board, ignite one row from bottom (*head fire*).
Use EITHER Experiment Set 2A or 2B.		
Experiment Set 2A. How does stand density affect fire spread?	Fires generally spread faster and combustion is more complete in dense standing fuels than in sparse fuels. Thus crown fire is more likely in dense than sparse forests. Clumping of fuels also affects potential for crown fire. **Explanation:** In a dense stand, heat and flames are more likely to reach nearby fuels.	Use long bolts for all models. Use the following matchstick densities/board (Figure M05-1): • 49 matches • 25 matches (50%), distributed evenly • 12 matches (25%), distributed evenly • 12 matches (25%) in clusters Ignite all boards from the bottom row.
Experiment Set 2B. How does stand density resulting from different fire histories affect fire spread?	Fires generally spread faster and combustion is more complete in dense forest stands, such as forests that have not burned in a long time, than in more open forests, such as stands that were frequently burned by low-severity surface fires. If trees are growing in clusters, the entire cluster may burn but not ignite other clusters. **Explanation:** When fuels are close together, as in a dense forest or a dense clump of trees, heat and flames are more likely to reach the fuels nearby.	Use long bolts for all models. A single board represents about 1/40 hectare (an area about 16 meters on a side). Use the following matchstick densities/board: • 49 matches to represent dense stands that have not burned in a century. • 25 matches to represent a less dense forest with evenly spaced trees. • 5 matches, spaced far apart, to represent open-grown that have experienced frequent low-severity surface fires. • 12 matches, distributed in clusters, to represent patchy forest structure that may have resulted from fires with varying intensity, including crown fire and surface fire. Ignite all boards from the bottom row.

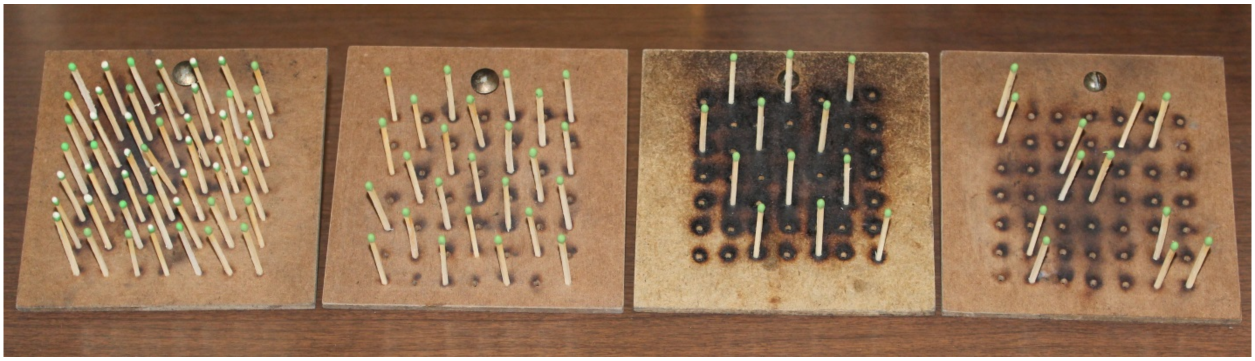


Figure M05-1: Setup of matches for Experiment Set 2A.

Materials and preparation:
Choose your location carefully. If you burn indoors, be aware that the experiments can produce flames 30-40 centimeters long. Can you do this safely in your classroom and without setting off a smoke alarm? Can you take your students to a lab where it will be safer? If you burn outdoors, be prepared for variable results, since even very subtle breezes will change the fire spread pattern and may overwhelm the effects of slope and stand density. In windy outdoor conditions, consider using a fireplace lighter and having students hold poster board around the matchstick stand to protect it from wind.

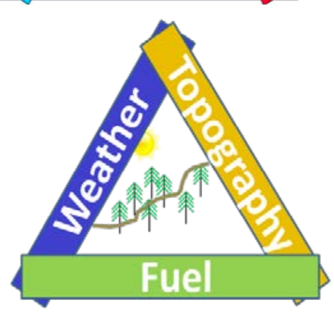
FireWorks Safety

When you do experiments with fire…

1. **Wear cotton clothing. No synthetic pants, soccer shorts, etc.**
2. **Wear closed-toed shoes. No sandals or flipflops.**
3. **Tie back loose sleeves.**
4. **Tie back loose hair.**
5. **Make sure a fire extinguisher is close. Make sure it is charged. Know how to use it.**
6. **Make sure spray bottles are close and filled with water.**
7. **Wear safety goggles when burning.**
8. ***Never* lean over a fire.**
9. **Extinguish burned materials with water before putting them in the trash. *Fire is not out if there is any smoke or heat coming from the fuels.***
10. **If a fire starts on you, stop, drop, and roll.**

Use fire ONLY if a responsible adult is working with you.

Have students work in teams to set up the matchstick forests for this activity, then ignite them one at a time so all students can observe all fires. You could also have student volunteers set up the matchstick forests ahead of the class period.



- The day before doing this activity, display the *FireWorks Safety* poster (*M02_FireWorks_Safety_poster.pptx*) and remind students to follow safety guidelines about clothing and hair when they get ready for school tomorrow.
- Get a package of hair bands to keep in your pocket so you can give them out as needed.
- Get four boxes of wooden kitchen matches (not provided in the trunk).
- Display the Fire Triangle poster (*Fire Triangle poster.pdf*) and the Fire Environment Triangle poster (*M05_FireEnvironmentTriangle*

for display.pdf)

- Download *M05_MatchstickForestExperimentDesigns.pptx*.
- Set up the teacher's lab bench with this equipment:
    - Fire extinguisher, fully charged
    - Two spray bottles, filled with water
- Set up a lab bench or other safe space for each student team, using the following equipment (available in the trunk):
    - 1 metal tray (i.e., cookie sheet)
    - 1 ashtray
    - 1 box of matches
    - 1 matchstick forest board
    - 1 ruler
    - A short and long bolt and 1 nut from the matchstick forest kit
    - 1 pair safety goggles
    - 1 nail (for removing burned matches from boards)
- 1 copy of **Handout M05-1** for each student
- Have a <u>metal trash can without a plastic liner</u> available in the room.

Procedure:

1. Do a **safety checkup** with students using the *FireWorks Safety* poster.

2. Explain: You already know about the Fire Triangle, which describes the basic nature of combustion. Wildland fire professionals use the Fire Triangle to understand combustion, and they also a second model, the Fire <u>Environment</u> Triangle (also called the Fire Behavior Triangle), to describe the complexities of fire when it burns in wildland fuels – which are a lot messier than the tidy matches and candles that we've been studying. The Fire Environment Triangle reminds managers of three things that control how fires behave in wildlands: fuel, weather, and topography. In this activity, we'll study the effects of slope (one facet of *topography*) and different arrangements of *standing fuels* – that is, patches ("stands") of trees or other vegetation, such as shrubs that have long stems and thick crowns and even grasses. In these experiments, we'll try to <u>not</u> change anything about weather conditions, although we may not be able to control that completely.

3. Discuss experimental design with the class, including the idea that you change only one variable at a time to learn its effects. An *experimental variable* is whatever you're investigating – in this case, slope (Experiment Set 1) or stand density (Experiment Set 2).

4. Project *M05_MatchstickForestExperimentDesigns.pptx*, showing Slide 1.

5. Hand out copies of **Handout M05-1**. Explain that we'll do one set of experiments together and talk through the answers, and then they'll complete the handout for the second set – so they should not write on it now.

6. Show students the matchstick forest model (masonite board, nuts and bolts) and discuss some variables that can be investigated with this model. Explain: the model is most often

used to investigate *crown fires*, that is, fires that burn through the tops of trees or shrubs, as opposed fires that burn on the forest floor (called *surface fires*) or in the organic material of the soil (called *ground fires*). We don't think of grass fires as crown fires, but the matchstick forest results can be applied to these *standing fuels* too.

7. Discuss Question 1 on the handout: We will investigate the effect of **slope** on fire spread.

8. Discuss Question 2 by developing one or more hypotheses about how slope will affect fire spread.

9. Discuss Question 3: What observations do we need to test the hypothesis? We suggest:

   - Time of ignition and time when fire goes out (used to calculate fire duration) or fire duration measured by stopwatch/timer
   - Number of match tips burned
   - Approximate maximum flame length (estimated at safe distance from flames)

10. Refer to Slide 1 in *M05_MatchstickForestExperimentDesigns.pptx.* Assign one experiment to each student team. Instruct students *not* to ignite their setup until everyone is ready. The matchstick forests will be ignited one at a time, so the whole class can observe and record data.

11. Have each team assign roles: Igniter (unless you want to do this yourself), timer, flame measurer, and data recorder. Remind students to dispose of burned matches in the ashtray or on the metal tray.

12. When all teams are ready, one team at a time:

   - Have them describe their setup.
   - One board at a time, have students ignite the boards by lighting the first full row of matches, and have them make observations/measurements.

13. After all 4 boards have been burned, complete any calculations (such as duration of burning). Discuss Questions 4-9 on the handout together

14. Discuss: "Using your understanding of the heat plume and Fire Triangle, explain how slope affects fire spread." (This is like Question 10 on the handout, except it refers to slope rather than stand density.)

15. Ask students how this model is like a real forest (flammable fuels with spaces between, highly ignitable "crowns" – which occur in some wildlands and not others, …). Then ask how its fuels are not like wildland fuels (no surface fuels, uniform tree distribution, …). Ask how the board is not like a patch of land (uniform terrain, trees tilt with the slope, …).

Assessment:

1. Explain: Now we will investigate the effect of *stand density* on fire spread. This is the arrangement of standing fuels (including trees, shrubs, and even grass stems) on a patch of land.
2. Have students answer Questions 1-3 on the handout.
3. Project either Slide 2 or 3 from *M05_MatchstickForestExperimentDesigns.pptx*, depending on which experiment set you plan to use.
4. Explain: Each team will set up one part of Experiment Set 2. When all are ready, we'll burn each setup as a class, so we will all get to observe every fire. Assign each student team to prepare one of the experimentals in Experiment 2A or 2B. They may switch team roles.
5. When all boards are ready, have the teams burn them one team at a time. Have students complete their handouts (questions 4-7) individually for all 4 experiments.
6. Have students answer Questions 8-9 on their own.
7. **Clean up:** Have students do cleanup. Make sure all burned materials and matches are out before you dispose of them – that is, there is no smoke and no heat being released. Use a metal trash can without a plastic liner. If in doubt, dump them in a bucket of water before putting in trash.

Evaluation. See the Answer Key below.

EXTENSION #1: After you do Experiments 1 and 2A or 2B, you can extend this activity to help students develop and test their own hypotheses. Here are some questions that they could explore using the same experimental materials:

1. What is the best placement and size for a fireline (where a swath of fuels is removed) in forests with various slopes and stand densities?
2. How does ignition pattern affect fire spread? (Compare ignition from a single point, a whole row of matches (from top, bottom, and sides), and all matches around the edge of the board.)
3. How useful is it to remove selected trees for the sake of reducing potential for crown fire on sites with different slopes and prevailing wind directions?
4. If you were planning to build a home in this plot of land, what would be the best location for it? Would you make any changes to the tree density around the home?

EXTENSION #2: You can also extend this activity by exploring other variables that affect fire spread, such as: moisture, matchstick height, wind, location of fire start (corner, middle, single tree, multiple trees), etc.

Handout M05-1: Matchstick Forest.

Name(s): ________________________

1. **Experimental question:** What is the effect of ______________________ on fire spread? This is the condition that will be changed – "varied" - from one experiment to the next, so it is called the *experimental variable.* In Experiment 1, the experimental variable was slope.

2. **Hypothesis:**

3. **Measurements needed:**

   Calculations needed, if any:

   How do you plan to ignite – from the top, side, or bottom row of matches?

Experiments 1-4 (below) refer to each team's experimental trial. Answer questions for all four experiments, not just your own.

4. **1st experiment** –
   a. What is the condition of the experimental variable? That is, how many matches are being used and how are they arranged?

   b. Measurements and calculations:

5. **2nd experiment:**
   a. What is the condition of the experimental variable?

   b. Measurements and calculations:

6. **3rd experiment:**
    a. What is the condition of the experimental variable?

    b. Measurements and calculations:

7. **4th experiment:**
    a. What is the condition of the experimental variable?

    b. Measurements and calculations:

After all experiments are done, answer the following:

8. Review your hypothesis (Question 2 above). Based on your observations, do you think your hypothesis was correct? If not, write a better one here:

9. Write a paragraph that answers Question 1 above. Show how the results of your experiments demonstrate your answer. Use your understanding of the heat plume and the Fire Triangle to explain.

Handout M05-1: Matchstick Forest Answer Key.

1. **Experimental question:** What is the effect of stand density on fire spread?

2. **Potential hypotheses:**
   - Fire will spread more easily through a dense stand than through an open stand.
   - Fire will spread easily through clumps of trees but will not spread easily through big openings between clumps.
   - If a clump of trees is uphill from a burning clump, it will ignite more easily than if it is downhill than the burning clump.

3. **Measurements needed:**
   - duration of burning
   - maximum flame height
   - number of matches burned…

   Calculations needed, if any:
   - Percentage of trees burned
   - Duration of burning if measured with a start time and an end time. Not needed if measured with a stopwatch.

   How do you plan to ignite – from the top, side, or bottom row of matches? Bottom row of matches

4-7. Obtain from M05_MatchstickForestExperimentDesigns.pptx, Slide 2 or 3.

After all experiments are done, answer the following:

8. Review your hypothesis (Question 2 above). Based on your observations, do you think your hypothesis was correct? If not, write a better one ….

9. Write a paragraph that answers Question 1 above. Show how the results of your experiments demonstrate your answer. Use your understanding of the heat plume and the Fire Triangle to explain. Fires spread faster and burn more completely in dense standing fuels (like the board with 49 matches) because heat and flames are more likely to reach nearby fuels. This is especially true when dense fuels are standing uphill from the burning fuels, because heat is rising convectively and heating the unburned fuels.

6. Ladder Fuels and Fire Spread: The Tinker Tree Derby

Lesson Overview: In this activity, students use a physical model to learn how the vertical arrangement of fuels affects the potential for fires to spread into tree crowns. This activity applies mainly to forests, shrublands, and woodlands.

Lesson Goal: Increase students' understanding of the relationship between fuel arrangement and vertical fire spread, especially in forests, shrublands, and woodlands.

Subjects: Science, Writing, Health and Safety

Duration: One to two half-hour sessions

Group size: Whole class, working in 4 teams to prepare

Setting: Indoor laboratory or outdoors

New FireWorks vocabulary: *ladder fuels, succession*

Objectives:

- Students can design a model tree and assess its ability to "survive" a surface fire.

Standards		6th	7th	8th
CCSS	Writing	4,10	4,10	4,10
	Language	1,2,3,4,6	1,2,3,4,6	1,2,3,4,6
	Writing: Science and Technology	4,10	4,10	4,10
NGSS	History of Earth	ESS2.A		
	Human Impacts	ESS3.B, ESS3.C		
	Engineering Design	EST1.A, ETS1.B,ETS1.C		
EEEGL	Strand 1	B, C, E, F, G		

Teacher Background: This activity explores the potential for a surface fire (burning in vegetation on the forest floor) to spread up into the crowns of overhanging trees. The more continuous the fuels, the more likely this will happen. Fuels that enable fire to climb from the forest floor to the crowns of trees are known as *ladder fuels*. Once fire is in a tree crown, it could spread directly from one tree crown to the next; such crown fires are usually more dangerous and harder to control than surface fires.

The Tinker Tree Derby is a competition among student teams. Each team constructs a "tinker tree" from a support stand, wire rods, and newspaper fuels. The goal is to design a tree that can "survive" a fire passing beneath (surface fire) but also has plenty of leaves so it can photosynthesize, continuing to grow and produce seeds. A team's success is tested by experimental burning. The tree that survives burning with the greatest potential for photosynthesis is the winner. Photosynthesis potential is quantified in this activity by the **length of branch with unburned "foliage"** (newspaper strips on branches) remaining after the fire. Figure M06-1 below shows how to set up the tinker trees.

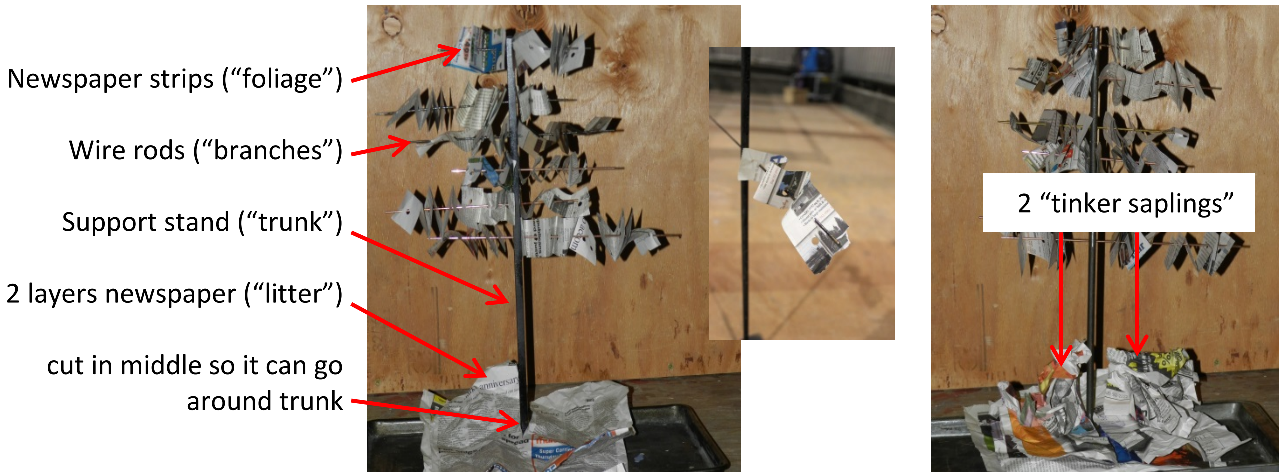


Figure M06-1. Setting up a tinker tree model. Place support stand ("trunk") on burning tray. For Phase 1 (shown at left), place 2 crinkled sheets of newspaper ("litter") around base of tree. Students insert as many wire rods ("branches") as desired into trunk. They thread hole-punched pieces of newspaper ("foliage") on branches. At outside end of foliage strips, use rod to punch hole (shown at center). For Phase 2 (shown at right), add 4 crinkled sheets of newspaper around base of tree and place 2 crumpled sheets ("tinker saplings") on top of them, 1 under each side of the tree.

The Tinker Tree Derby has two phases, which enable students to see the effects of two different amounts of surface fuels. Phase 1 uses relatively light surface fuels, and Phase 2 uses much more fuel. Any tinker trees that survive Phase 1 (the "Qualifying Round") will be tested again in Phase 2 (the "Championship Round"). **Thus it is important to not moisten or disturb the trees after they are burned in Phase 1.** The 2 phases model the potential for accumulation of surface fuel and development of the understory (tree saplings and shrubs) over time, during the process of *succession* (the process of change over time). We recommend that you don't give students any details about Phase 2 until after Phase 1.

Materials and preparation:
Do this activity in an area with good ventilation and a hood or a fairly high ceiling. Smoldering pieces of newspaper can rise as high as 20 feet on the heat plume. If your laboratory hood is not adequate, consider igniting the Tinker Trees outdoors – but not on a windy day. Use a large area that far from dry grass, bark chips, and other fuels. Have a bucket of water and a hose available, with the water on. Have another adult help "patrol" for burning materials.

The day before doing this activity, remind students to follow the safety guidelines about clothing and hair when they get ready for school tomorrow.

You will need a lot of newspaper. Get students to prepare

- four bags (1 per team), each containing about 30 strips of newspaper approximately 40 cm long and 4 cm wide. Each strip has to be folded accordion-wise and hole-punched so it can be threaded onto a wire rod to represent tree foliage. The strips represent tree foliage in the tinker tree model.
- 24 half-sheets of newspaper, 25 x 35 cm. These represent litter in the model.
- 8 quarter-sheets of newspaper, approximately 25 x 20 cm. These represent saplings in the model.

Set up four work stations. Each station should have

- 1 Tinker Tree support stand
- 1 pair of safety goggles
- 1 oven mitt
- 1 ashtray
- 1 metal tray with a support stand on it
- 10-15 segments of wire rod
- 6 half-sheets of newspaper, 25 x 35 cm
- about 30 narrow strips of newspaper, cut into strips and hole-punched
- 2 quarter-sheets of newspaper
- paper towels for clean-up
- 1 spray bottle, filled with water

In addition, you will need:

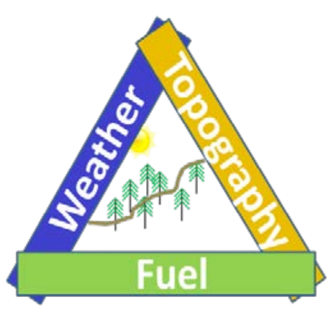
- 1 measuring tape
- 1 fire extinguisher (make sure it is charged and know how to use it)
- 1 "Tinker Trees" kit with 4 pendants (awards for the winners in each phase)
- 1 box of kitchen matches
- A handful of hair ties, in case students need them

Have an empty *metal* trash can *without a plastic liner* available in the room.

Display Posters:

- FireWorks safety
- Fire Environment Triangle

Download "ladder_fuels.jpg"



FireWorks Safety

When you do experiments with fire...

1. Wear cotton clothing. No synthetic pants, soccer shorts, etc.
2. Wear closed-toed shoes. No sandals or flipflops.
3. Tie back loose sleeves.
4. Tie back loose hair.
5. Make sure a fire extinguisher is close. Make sure it is charged. Know how to use it.
6. Make sure spray bottles are close and filled with water.
7. Wear safety goggles when burning.
8. *Never* lean over a fire.
9. Extinguish burned materials with water before putting them in the trash. *Fire is not out if there is any smoke or heat coming from the fuels.*
10. If a fire starts on you, stop, drop, and roll.

Use fire ONLY if a responsible adult is working with you.

Make 1 copy of **Handout M06-1. Tinker Tree Derby instructions and Rules** for each team and 1 copy of **Handout M06-2. Tinker Tree Model vs. Reality** for each student.

Copy this table onto the board (or a sheet of paper if you're burning outdoors):

Team name	Qualifying Round: Surviving foliage (cm)	Championship Round: Surviving foliage (cm)

Procedure:

1. Explain: In this activity, we'll look more carefully at the Fuels side of the Fire Environment Triangle (AKA Fire Behavior Triangle). We'll think about how fuels are arranged – especially in forests and shrublands – and how the arrangement of fuels changes as plant communities change over time, a process called *succession*.

2. Project this image (ladder_fuels.jpg). Explain: If fuels are continuous from the forest floor into the tree crowns, we call them *ladder fuels.* A surface fire can climb them like a ladder and get into the crowns, where it becomes much more powerful than a surface fire and more difficult to control.

3. Distribute **Handout M06-1: Tinker Tree Derby Instructions and Rules**. Explain: This is a competition between teams, where you apply what you know about fuels to design a model tree that can "survive" a surface fire without having the fire climb into the treetops, thus becoming a crown fire. The winning tree will not just avoid being burned up; it will also have lots of foliage left, so it can continue to photosynthesize, grow, and reproduce after the fire. Therefore, your task is to have your tree avoid crown fire and at the same time have lots of foliage left after the surface fire.

4. Have each team read Handout M06-1 together. Answer any questions. Show them how you will determine the tree's score: You will measure the length of branch (cm) that still has unburned newspaper ("live foliage") on it – NOT the total amount of newspaper or its weight. Ask the class to tell you one thing that will disqualify them from competition. (Any moisture that they add to their model.)

5. **Do a safety briefing** using the *FireWorks Safety* poster. Review the location of spray bottles and a fire extinguisher.

6. Give the students ~10 minutes to construct their trees. Watch for moisture violations! Then have them ignite the trees <u>one team at a time</u>, so everyone gets to see every fire.

Phase 1 - Qualifying round:

A. One team at a time…

- Ask for the team name and have a student write it on the board.
- Check and modify the surface fuels to make them similar among trees so this variable will not confound the results.
- Have the students start the fire <u>by igniting two corners along one long edge</u> of the metal tray. If they all use the same ignition pattern, this variable will not confound the results.
- When the fire is out, use the measuring tape to determine the <u>tree's score: the length of branch (cm) that still has unburned " foliage."</u> Have a student record this on the board under "Qualifying Round" for that team.

B. After all teams have completed a burn, determine the winner of the Qualifying Round, that is, the team with the greatest total branch length with living foliage.

C. Award Tinker Tree Derby Champion badges to the winning team. They get to wear the badges until the end of class.

Phase 2 – Championship Round:

D. For all teams whose tinker trees survived the Qualifying Round, have students leave the surviving foliage intact but gently remove the ash of the burned surface fuels and replace it with <u>four</u> new layers of surface fuel (crumpled half-sheets of newspaper). Teams with trees that did not survive the Qualifying Round (zero centimeters of unburned foliage) get to observe.

E. Explain: Surface fuels often accumulate as plant communities change over time without fire. Trees reproduce, and shrubs develop under the forest canopy in this process, which is called succession.

F. Have each team take two smaller pieces of newspaper (quarter-sheets), crumple them up, and place one on each side of their tinker tree trunk <u>under the branches</u>. These are "tinker saplings," young trees that grow up under the old survivor.

G. One team at a time, check their fuels… have them ignite… and determine the tree's score. Determine the winner, if any. Award Tinker Tree Grand Champion badges to the winning team. They get to wear these until the end of class.

Assessment: Have each student complete **Handout M06-2: Tinker Tree Model vs. Reality.**

Evaluation:
Question 1. Assess changes individually.

Question 2. Examples of model shortcomings:

- Tinker tree's metal trunk cannot be damaged by fire.
- Tinker tree is two-dimensional (has foliage only on 2 sides of trunk).
- Foliage is not alive, so it has no moisture and is not changing with the seasons.
- Tinker tree has no roots that could be damaged by fire.
- Tinker tree does not grow taller, gain new branches, or shed old ones as years go by and succession occurs.

Question 3. A has more surface fuels, larger surface fuels, more ladder fuels, and closer spaced tree crowns than B. Thus A is more likely to have a crown fire on a dry, windy day than B. However, B is more open than A (i.e., lower stand density), so the wind at the ground surface is likely to be stronger and thus surface fire is likely to spread faster in B than in A. (A point not covered in this activity: Because of its heavy fuels, A is more likely to have a very severe surface fire than B – which could kill the trees even without burning their crowns.)

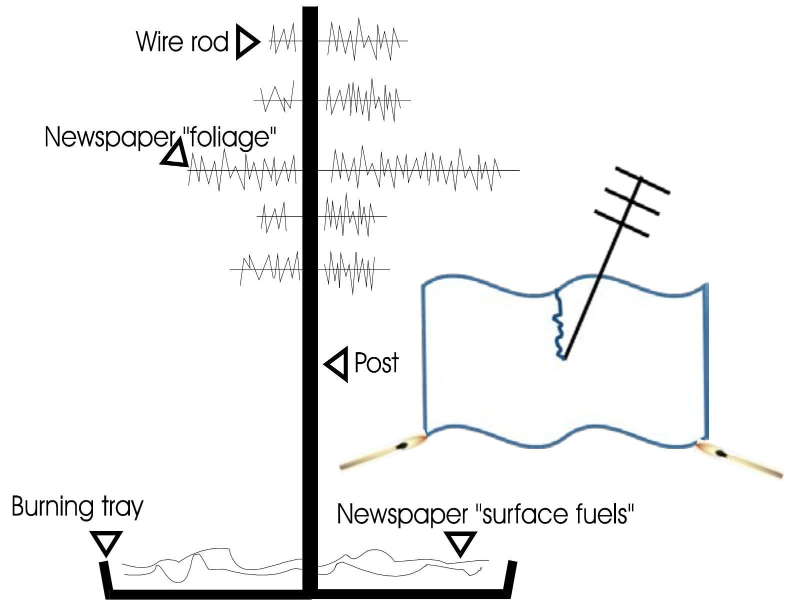
	Excellent	Good	Fair	Poor
1. Changes to Tinker Tree	>2 changes	2 changes	1 change	0 changes
2. How Tinker Tree is not real	>2 examples	2 examples	1 example	0 examples
3. Compare fuels and potential fire behavior	-Described 3 or more differences in fuels/density and explained 1-2 differences in potential fire behavior.	-Described 2 differences in fuels/density and explained at least crown fire potential.	-Described 1 difference in fuels/density or explained crown fire potential.	-Did not address questions.
3b. Use terms correctly (surface fire, crown fire, ladder fuels, stand density)	-Correctly used 4 terms	-Correctly used 3 terms.	-Correctly used 2 terms.	-Correctly used 1 or no terms.

Handout M06-1: Tinker Tree Derby Instructions and Rules

A tinker tree is a two-dimensional model of a tree. Its trunk is a lab support stand. Its branches are rods stuck through holes in the trunk. Its leaves are strips of newspaper. Your goal is to design and build a tinker tree with a crown that does not burn when a fire burns the surface fuels beneath it. Your job could be easy—just put together a tree with no leaves. But your tree must also have *foliage* (leaves) to win the Tinker Tree Derby – the more, the better. You have to figure out how much foliage to use and how to arrange it on the tree so the tree can survive a surface fire.

Procedure:

1. Place a support stand (metal post) in the center of the metal tray.
2. Crumple up two half-pages of newspaper. These are your litter and other surface fuels. Flatten them out a bit, but make sure that some air can get between the layers.
3. Cut or tear a line from one edge of the newspaper pieces to the middle. Then place both layers on the support stand base, with the stand's post at the center.
4. Slide wire "branches" through the holes in the post. You may use as many or as few branches as you want.



5. Use the long, narrow strips of newspaper for foliage. Slide a foliage strip onto each tinker tree branch. For short branches, you may shorten the newspaper strip. Use the branch to poke a small hole at the outer end of the foliage strip rather than using a punched hole, so the newspaper won't fly off the branch once you start burning.
6. Teams will ignite their tinker trees one at a time. When the teacher tells you it's time to ignite yours, start the fire by igniting two corners along **one long edge of the metal tray**.

Rules:

- Do not use any moisture on your tinker tree or experimental setup before it is burned. **If you do, your tree will be disqualified.**
- Do not move or moisten your tree's foliage after you have underburned it.
- Do not hang foliage so it dangles into the branches below.

Keeping score: After you have underburned your tinker tree, the teacher will assign it a score: **the number of centimeters of branch still covered by unburned foliage**. If your score is greater than zero, your tree has qualified for the Championship Round of the Tinker Tree Derby. Do not change anything about it until you receive further instructions.

Handout M06-2. Tinker Tree Model vs. Reality

Name __________________________

1. List at least three changes you would make to your Tinker Tree or surface fuels to increase the tree's chances of surviving a surface fire. Explain why you would make each change.

2. List at least three ways in which the Tinker Tree model does *not* resemble a real tree.

3. Study the photographs below. Write a paragraph that answers these questions:
    - How are the fuels in "A" different from those in "B"?
    - How are the different fuels likely to affect the kind of fire that would occur there on a dry, windy day?
    - How is the stand density (which was covered in the last activity – Matchstick Forests – likely to affect the kind of fire that would occur there on a dry, windy day?

    Use the following terms correctly in your explanation: surface fire, crown fire, ladder fuels, stand density.

A.

Dave Powell, USDA Forest Service, Bugwood.org.

B.

Dave Powell, USDA Forest Service, Bugwood.org.

7. Fuel Properties: The Campfire Challenge

Lesson Overview: In this activity, students explore how different properties of fuels affect fire behavior – especially how hard it is to ignite fuels and how long they are likely to burn. Students consider various combinations of fuels ("fuel recipes"), predict how they will burn, then test their hypotheses. Then students demonstrate what they have learned in a speaking and listening activity ("dynamic Socratic circle with a brilliance board").

Subjects: Science, Health and Safety, and Speaking/Listening

Duration: Two to three half-hour sessions

Group size: Teams of 3-4

Setting: Outdoors or laboratory with good ventilation

New FireWorks vocabulary: *duff, fuel arrangement, fuel load, fuel moisture*

Lesson Goal: Increase students' understanding of properties of wildland fuels and how they affect fire spread and fire duration.

Objectives:

- Students can arrange specific fuels to build a small campfire that is relatively easy to ignite and can burn for a relatively long time.
- Students can discuss the ignition and burning of various combinations of fuels in a speaking and listening activity.
- Students can describe how characteristics of wildland fuels affected an experimental campfire.

Standards:		6th	7th	8th
CCSS	Writing	4,7,10	4,7,10	4,7,10
	Speaking and Listening	1,4,6	1,4,6	1,4,6
	Language	1,2,3,6	1,2,3,6	1,2,3,6
	Writing: Science and Technology	4,7,10	4,7,10	4,7,10
NGSS	Energy	ETS1.A,B		
	Structure and Property of Matter	PS3.A		
	Structure, Function, and Information Processing	LS1.A		
	Engineering Design	ETS1.A,B		
EEEGL	Strand 1	A,B,C,E,F,G		

Teacher Background: Anyone who has built a campfire knows that you have to choose your fuels wisely and arrange them carefully. Four fuel properties influence fire behavior: amount (known as fuel load or loading), size, moisture content, and spatial arrangement. These properties determine how flames heat the fuels and how much oxygen is in contact with them, and thus how quickly they will ignite and how long they will burn.

1. How much fuel is there? All other things being equal, the more fuel you have, the longer your fire can burn and the more heat it can produce… if you can get the fuels to ignite.
2. What sizes are the fuels?
   - The smaller the fuel particles, the more easily the heat plume can engulf them and heat them to ignition temperature – and the more oxygen that is available for burning. For example, consider the challenge of igniting a big, dead log versus a dead pine needle. Small pieces are usually easiest to ignite (if they are dry, of course), because there is ample oxygen, and even a small heat plume can surround them and heat them up fast. But because they are small, they burn up quickly.
   - Large fuel particles tend to burn slowly because it takes time for the outside surface to burn away, exposing a new layer of fuel to heat and oxygen.
3. How moist are the fuels? The drier the fuels, the less heat needed to dry them out, so the more easily they will ignite and the more completely they will burn. Moisture makes fuels hard to ignite, makes them burn slowly, and creates more smoke. This is because the moisture must be removed before a particle can be heated to ignition temperature.
4. How are the fuels arranged?
   - How "fluffy" are the fuels? The *fluffiness* of fuels determines how much oxygen is available for combustion. An important skill in building a campfire is to get the spatial arrangement of fuels "just right" so lots of heat and oxygen are right next to the unburned fuels. Fuels have to be somewhat near each other for fire to spread from one piece to another. The pieces can be too loosely packed for heat to reach from one particle to the next, making it hard for fire to spread. For example, if you crumple up 20 pieces of newspaper and scatter them across a large room, a fire cannot spread from one piece to another. But the pieces can also be too tightly packed for heat and oxygen to disperse among them. For example, a tightly piled stack of newspapers will be hard to start on fire. (Once started, however, that pile of newspapers could smolder for a long time.)
   - How fuels arranged vertically? If easy-to-ignite fuels are placed below hard-to-ignite fuels, the rising heat helps ignite the upper fuels. We use this principle in building a campfire when we place small particles ("fine fuels") – which we call kindling - near the bottom of the fuel bed and then place layers of large ("coarse") fuels above. A land owner who wants to prevent crown fires notices heat's tendency to rise too, and makes sure there are big gaps between the surface fuels and the tree crowns. If the gaps are small, the fire can spread up the ladder fuels provided by young trees, shrubs, and low branches – and reach the crowns. This principle also applies to ladder fuels in forests, as students learned in Activity 6.

This activity investigates one aspect of the Fire Behavior Triangle directly: *fuels.* Indirectly, it also investigates *weather,* since that is what controls the moisture of fuels. Weather is explored more fully in Activity 8.

Materials and preparation:

This activity is best done outdoors because it can be messy and smoky; however, do not do the activity outdoors on a windy day. Use a large area that is far from dry grass, bark chips, and other fuels. Have a bucket of water and a hose available, with the water turned on. Have another adult help "patrol" for safe use of matches and watch burning materials. If you do the activity indoors, use a laboratory with good ventilation (i.e., a hood).

- At least two days ahead of time, obtain enough of these dead fuels to do the activity—that is, about a dozen "handfuls" of each:
  - dead conifer needles
  - small twigs (less than 0.5 centimeter in diameter)
  - large sticks (about 2-3 centimeters in diameter)

  Spread them out in a dry place so they are uniformly dry by the time you use them.

- Make sure you have enough dry peat moss (*duff*) to do the activity. Some is usually included in the trunk.

- The day before you do the activity, remind students to dress appropriately for burning. Post and refer to the FireWorks safety poster.

- The day before you do the activity, collect enough green conifer needles to do the activity.

- Copy the ingredients for the fuel recipes onto the board (or a poster, if you plan to do the activity outdoors):

Recipe	Ingredients
1	Dead, dry conifer needles Duff Green conifer needles
2	Dead, dry conifer needles Small twigs Big sticks
3	Small twigs Duff Big sticks
4	Duff Big sticks Green conifer needles

- Set up your teacher area with:
  - o The Fuel Recipe box. Be sure to select the recipes labeled “M” for Middle School students.
  - o 5 boxes or grocery bags containing fuels (dead, dry conifer needles; small twigs (<0.5 cm diameter); dry peat moss, which serves as duff; big sticks (2-3 cm diameter); green needles). Label the bags. You can use the tie-on labels from the trunk.
  - o Fire extinguisher
    2 spray bottles, filled with water, and additional water (bucket, charged hose, etc.) to ensure you can easily put a fire out

- Set up 4 student work stations, each with
  - o one 9” diameter aluminum pie tin with tilted edges
  - o optional 1 metal tray (i.e., cookie sheet underneath the pie tin)
  - o 1 match box with 7 matches
  - o 1 ashtray
  - o 1 pair of safety goggles
  - o 1 oven mitt

- Have an empty *metal* trash can *without a plastic liner* available.

Procedures:

1. Explain: Students will work in teams to build small “campfires” using specific combinations of fuels. The experimental questions are:
   - What kinds of fuels are easiest to ignite?
   - What kinds of fuels burn longest?
2. Explain what *duff* is: partly decomposed plant and animal matter lying on or in the soil. There can be a huge amount of duff on the ground – as under an old tree or in a peat bog that may have “organic soils” a meter deep or more. Or there can be very little duff – as in dry places where plants grow slowly. Remember from Activity 5 that a fire burning in the duff is called a ground fire. In this experiment, dried peat moss is used to represent duff.
3. Using the recipes listed on the board, ask students to “vote” on:
   - which will be easiest and hardest to start on fire
   - which will burn out in the shortest time and which will last longest

   Record the votes on the board. These represent the class’s hypotheses.
4. Group students into 4 teams.
5. Explain the procedure. The whole team is responsible for safety. If any student is injured, the team must alert the teacher and use water to put out their campfire. Each team will:

a. Draw a recipe from the Recipe Box.

b. Collect the three ingredients on their recipe from the labeled ingredient bags. Fuels are "measured" by the "handful," which is subjective, but the point is to use about the same amount of each fuel in a campfire.

c. Discuss and work together to arrange the fuels. The goal is to make the fuels ignite as easily as possible and burn as completely as possible. The fuels must fit inside the pie tin; they may not spill over the sides. The matches can be used to ignite the campfire or added into the fuel array. Obviously, at least one must be used for ignition.

d. Have a teacher or other adult verify that they have met the requirements before ignition.

e. After ignition, they <u>may not</u> rearrange the fuels, but they <u>may</u> blow on the fire. Dispose of burned matches in the ashtray or in the campfire.

6. Have the students ignite their campfires. Monitor their progress and watch for safe practices.

7. After all teams have either burned all their fuels or used all their matches, have each team explain to the class their strategy for arranging fuels and how they might do it differently the next time. Note that some campfires may still be burning.

8. **Clean up:** Make sure all burned materials and matches are out before you dispose of them – that is, there is no smoke and no heat being released. Especially check large sticks and duff, which may smolder for a long time. Stir the fuels and feel for heat. Use an empty metal trash can without a plastic liner. If in doubt, dump fuels in a bucket of water and leave them there overnight before putting in trash.

9. Set up the following speaking/listening activity, which is called a Dynamic Socratic Circle with a Brilliance Board. In this activity, students will discuss the four hypotheses, fuel properties, heat transfer, and concepts from the Fire Triangle. Instructions:

a. Divide the class into three groups (A, B, C). Then arrange the chairs in the room to make an inner circle of chairs (enough chairs for each student in group A) and an outer circle of chairs (enough chairs for each student in group B). Have each student in group C stand by the board and be ready to write.

b. Give the individuals in the inner circle a question that they must discuss. All must contribute to the discussion. Students in the outer circle can join the conversation in the inner circle by tapping the shoulder of a student in the inner circle who has contributed. Then these two students will switch places. While groups A and B (inner and outer circle) are speaking and listening, group C at the board is writing down brilliant and important points and questions that come up during the conversation. Tell Group C that it is good to repeat points because after the discussion the class will analyze the board for trends.

c. Rotate the groups so each has had a turn at each station. When there is little left to be said or information is being repeated, change the question.

The questions are listed below. Explain that students should use their observations from the experiments and their knowledge of the Fire Triangle and heat transfer in their conversation. In the discussion, encourage students to address some of these characteristics:

1. Amount of fuel - called *fuel loading*
2. Size of fuel particles
3. *Fuel moisture*
4. *Arrangement* of fuel particles (how fluffy or tightly packed are they? How are they arranged vertically?)

See the discussion of these in the Teacher Background section, in red print.

Questions:

- Were any of your hypotheses incorrect?
- Were any of your hypotheses correct?
- Which recipe was the easiest to start on fire?
- Which recipe was the hardest to start on fire?
- How does the Fire Triangle explain the easiest/hardest fires to ignite?
- Which recipe burned out the quickest?
- Which recipe burned the longest?
- How does the Fire Triangle explain the quickest/longest fires?
- How did fuel fineness affect fire?
- How did fuel moisture affect fire?
- How did fuel size affect fire?
- How did the fluffiness of fuels affect fire?
- How did the vertical arrangement of fuels affect fire?

Assessment:

1. Participation in each circle of the speaking/listening activity
2. Have each student write down the recipe he/she used and then use the four fuel properties to explain why their recipe burned as it did (easy or hard to ignite, burning out quickly or slowly).

Evaluation:

	Excellent	**Good**	**Fair**	**Poor**
Inner Circle	Built upon peer's comments, greatly contributed to conversation, and encouraged others to speak.	Contributed to conversation.	Did not contribute, but was actively listening.	Disruptive to conversation
Outer Circle	Tapped in once a student had spoken,	Student was willing to leave the inner circle	Did not tap in, but was actively listening	Disruptive to conversation

	encouraged others to tap into the inner circle.	when tapped out.		
Brilliance Board	Consistently writing brilliant points and questions on the board.	Student was actively listening and occasionally wrote on the board.	Did not participate, but was actively listening.	Disruptive written remarks.
Written explanation of recipe's success	Addressed 4 fuel properties in regard to experimental fire. Addressed both ease of ignition and duration of burning.	Addressed 3 fuel properties in regard to experimental fire. Addressed both ease of ignition and duration of burning.	Addressed 1-2 fuel properties. Addressed either ease of ignition and duration of burning.	Assessed 0-1 fuel property. Did not address ease of ignition or duration of burning.
	For discussion points about each fuel property, see the discussion of fuel properties in the **Teacher Background** above (in red print).			

8. Fire Behavior, Fire Weather, and Climate

Lesson Overview: In this activity, students learn about the behavior, weather, and other aspects of a real wildland fire – the Storrie Fire of 2000 on the Plumas and Lassen National Forests. Then they create a podcast about the fire and potential effects of global climate change on wildland fires.

Lesson Goal: Students will be able to communicate the effects of weather on fire spread and possible relationships between global climate change and wildland fires.

Objectives: Students can use information on the history of the Storrie Fire, weather conditions, and global climate change to create a podcast that

- catches the audience's attention with a human-interest angle,
- describes relationships between fire weather and fire spread on a certain date, and
- discusses the possible influence of global climate change on wildland fires.

> **Subjects:** Reading, Writing, Speaking and Listening, Math, Science
>
> **Duration:** Two 30-minute sessions
>
> **Group size:** Students work in groups of 2 or more
>
> **Setting:** Classroom
>
> **New FireWorks vocabulary:** *This activity uses specialized vocabulary used by wildland fire managers. Students may need to look up some definitions in order to complete this activity. The definitions are available at:* https://gacc.nifc.gov/nrcc/dc/idgvc/dispatchforms/glossary.pdf

Standards:		6th	7th	8th
Common Core ELA	Reading Informational Texts	3,4,7	3,4,7	3,4,7
	Writing Standards	1,2,3,6,7,8	1,2,3,6,7,8	1,2,3,6,7,8
	Speaking/Listening	1,2,4,5,6	1,4,6	1,4,6
	Language Standards	1,2,3,4	1,2,3,4	1,2,3,4
	Writing: Science/Technology	3,4,7,9,10		
NGSS	Weather and Climate	ESS2.D		
	History of Earth	ESS2.A		
	Earth's Systems	ESS3.A		
	Human Impacts	ESS3.B, ESS3.C		
	Engineering Design	ETS1.A,B		
EEEGL	Strand 1	A,B,C,E,F,G		
	Strand 2.1	A		

Teacher Background: In this activity, students explore how weather affects fire behavior, and they consider how climate change may affect wildland fires. They can complete the activity and assessment with information in **Handout M08-2. Storrie Narrative** and the PowerPoint presentation, which include official records from the Storrie Fire (Plumas and Lassen National Forests, started on August 17, 2000), data from a nearby weather station, and data describing global climate change. They may choose to supplement the resources with other information, but if they do so, they must document their sources.

The assessment for this activity (**Handout M08-1. Podcast for National Radio**) is to create a podcast in which students report to teenagers throughout the nation on how the Storrie Fire affected people, how its spread was related to weather, and how it might be an example of fires to come because of global warming.

If you are interested in exploring the history of specific wildland fires or would like more information on relationships between climate change and wildland fire, you may want to consult some of these websites. Several of them are referenced in **Handout M08-2** and the PowerPoint:

https://inciweb.nwcg.gov/	Information on the size, status, and other features of current fires throughout the United States
https://www.nifc.gov/fireInfo/fireInfo_main.html	National Interagency Fire Center – coordination and information for wildland fire programs nation-wide
https://gacc.nifc.gov/	Geographic Area Coordination Center – a portal for each major geographic region in the United States. Content differs by region, but most sites have regional news, maps, and other detailed information.
https://gacc.nifc.gov/nrcc/dc/idgvc/dispatchforms/glossary.pdf	Glossary of Wildland Fire Terminology, published by the National Wildfire Coordinating Group in November 2008
https://www.fs.usda.gov/ccrc/topics/wildland-fire	Information on the relationship between climate and wildland fire, hosted by the Forest Service's Climate Change Resource Center. Includes links to many video segments, from 5 to 30 minutes long.

Materials and preparation:

1. Read through **Handout M08-1. Podcast for National Radio**, **Handout M08-2. Storrie Narrative**, and the PowerPoint, and decide how much of that information to go over as a class and how much to assign for independent reading and study.

2. Download the PowerPoint M08_*StorrieFire&ClimateChangeData.pptx* and make it available to students, either electronically or in print.
   This PowerPoint presentation has 3 distinct parts:
   1) Data on the Storrie Fire's growth and staffing
   2) Weather and fuel moisture data during the time of the fire
   3) Information on global climate change
3. Decide if you are going to go through the presentation in class or give each student or team access to it. The slides and narrative for the presentation are shown at the end of this activity.
4. Make a copy of the Assessment (**Handout M08-1. Podcast for National Radio**) and **Handout M08-2. Storrie Narrative** for each student or team.
5. Make sure students have the equipment needed for recording their sound effects and podcast.

Procedure:

1. Explain: We have learned about theories and models of fire spread. Now we will study the spread of an actual fire, the Storrie Fire that burned more than 56,000 acres (about 90 square miles)[3] in the Plumas and Lassen National Forests in the year 2000. You will look at daily reports from fire managers and graphs that show how much the fire grew each day. You will also look at weather reports from the time when the fire was burning. Finally, you'll look at data on global climate change and consider whether climate change might be making fires like the Storrie Fire more common.

2. Briefly explain the assessment (described in **Handout M08-1**). Then go through **Handout M08-2** and the PowerPoint presentation or assign it for students to view and study: M08_*StorrieFire&ClimateChangeData.pptx* (shown at the end of this activity).

3. Remind students that they are welcome to obtain additional information, but they must get it from reliable sources and document their sources.

[3] Data on wildland fires are still recorded in US Standard ("English ") units rather than metric units. US Standard units are used throughout this lesson. It is acceptable for students to use US Standard units in their podcasts.

Assessment: Give each student or team a copy of **Handout M08-1**. Go over the assignment and answer questions, so they know what is required.

Evaluation:	**Excellent**	**Medium to Poor**
Structure: Introduction, Transitions, Conclusion, and Creativity	All present	Not all present
Length and sound effects	The presentation was close to 5 minutes in length and included three relevant sound effects that enhanced the podcast.	The presentation was greatly under or over five minutes. The presentation failed to include 3 or more sound effects or included sound effects that were irrelevant and distracting.
Human interest angle	Present, credible, and engaging	Not present, not credible, or not engaging.
Information about weather and fire spread	Accurate, based on information in lesson (or other factual information with sources documented)	Inaccurate or not present; if based on information not in lesson, not documented.
Relationship between climate change and occurrence of large, severe fires	Accurate, based on information in lesson (or other factual information with sources documented)	Inaccurate or not present; if based on information outside of lesson, not documented.

Handout M08-1. Podcast for National Radio

Work with your partner(s) to create a 5-minute podcast for a national radio station that is run by and for teenagers. The year is 2000. The date is any day between Aug. 17 and Sept. 11 when a change in the weather affected fire spread. Look at records from the Storrie Fire in order to choose a date that might be interesting to report on.

You have 4 sources of information:

- **Handout M02-2. Storrie Narrative.docx.**
  - Daily narrative reports from the Incident Command Team
- **PowerPoint presentation. StorrieFire&ClimateChangeData_MiddleSchool.pptx**
  - Data on the Storrie Fire's growth and staffing (Slide 3)
  - Data on weather and fuel moisture during the time of the fire (Slides 4-7)
  - Information on global climate change (Slides 8-12)

You may obtain other information too. If you do, be sure to record your sources, in case someone in your audience – or your teacher – asks for documentation.

You have 3 goals:

1. Give your audience some reason to care about the fire – some human-interest angle. (Perhaps they've been hearing about it in the national news. Perhaps they know people who live in the area where the fire is occurring. Perhaps you want to emphasize highway closures, safety and injuries, or evacuations. Perhaps you want to emphasize potential effects on timber value or wildlife habitat….)
2. Let your national audience know about the fire's recent behavior and how the weather in the last day or two has affected it. You can use weather reports from the fire managers' daily journal (in the Word document) and also from a nearby weather station (in the PowerPoint document).
3. Comment on whether some places in the world, including the Sierra Nevada, might see more fires like the Storrie Fire because of global climate change. You can use information from the PowerPoint document.

Your podcast must include an introduction, transitions, a conclusion, and at least three appropriately placed sound effects. It will help to have a written outline or script before you record.

Be as creative as you can. This is your opportunity to be artistic, unique, and show what you have learned!

Handout M08-2. Storrie Fire Narrative

In August, 2000, the Storrie Fire burned about 90 square miles in the northern Sierra Nevada and southern Cascades. A wildfire as big and dramatic as this is recorded in many ways. There are newspaper and television reports, personal messages from people who are evacuated or working on the fire, thousands of photographs, and official records. This report contains just 1 kind of information from official records about the Storrie Fire: the fire managers' journal.

As soon as a wildfire is found, a team of fire experts is assigned to manage it. This "Incident Command Team" (also called an "Incident Management Team") must file a report every day that summarizes the day's fire behavior, management actions, and management concerns. Concerns might include safety worries, road closures, and expected changes in the weather. An Incident Command Team may only stay for a few days or weeks before it is replaced by a new team, but that doesn't change the reporting requirements: A report is due every day, and it has to contain a "narrative," which we might call a journal entry. The managers' daily journal entries become part of the permanent record about the fire.

Here are the fire managers' journal entries for the Storrie Fires, starting with the day the fire started (August 17, 2000). The entries cover every day until the fire was declared totally "contained" (September 9) and then continued for 2 more days. The fire was finally declared "out" on November 30, 2000.

People in every profession use special words and phrases that may sound strange to the rest of us. Wildland fire professionals are no exception, so you will find unfamiliar terms in the reports below. Fortunately, you can find out what they mean in the *Glossary of Wildland Fire Terminology* (https://gacc.nifc.gov/nrcc/dc/idgvc/dispatchforms/glossary.pdf).

Fire cause: Started by crew welding materials on the railroad tracks

Nearest town: Storrie, California

Daily narrative reports (journal entries) from Incident Command Team:

17-Aug-00 The fire is burning is steep rugged terrain with numerous cliffs and canyons. Rolling rock and debris are hampering access. There have already been three minor injuries from rolling material and tactics have been changed to reduce this risk. There is a real threat to structures along HWY 70 and Pacific Gas & Electric facilities in the area. The temperature on the fire was in the mid 80's with humidities in the single digits. The fire made major runs upslope to the ridge during the day and laterally up canyon because of strong local canyon winds. This fire has the potential to go to multiple thousands of acres because of terrain and access. Scott Vail's California Type I Incident Management Team is due to take the fire tomorrow morning.

18-Aug-00 The fire is burning in steep rugged terrain with numerous cliffs and canyons. Rolling rock and debris are hampering access. There have already been four minor injuries from rolling material.

Vail's Team took control of the fire this afternoon. The fire is burning actively. A significant spot fire has established itself approximately one mile ahead of the main fire. Threats are to PG&E facilities/powerlines, Pacific Crest Trail, some structures, and Highway 70. Highway 70 remains closed.

19-Aug-00 The fire made major runs to the northeast this afternoon. Grew by 5,000+ acres today. Information on the fire is sketchy because of smoke. There's a 700+ acre spot fire on the south side of Hiway 70 in Buck Lake Wilderness. Main fire is moving in Yellow, Chips, and Indian Creek drainages. Pre-cautionary evacuation notices have been issued at the Three Lakes, Caribou Road, Seneca, Butt Lake Campgrounds, and the small town of Belden.

20-Aug-00 TODAY'S FIRE ACTIVITY WAS MINIMAL WITH A VERY STABLE ATMOSPHERE RESULTING IN LITTLE ACREAGE INCREASE. GOOD PROGRESS WAS MADE ON THE SOUTH END OF THE FIRE INCLUDING BURNING OUT AND HOLDING OF INDIRECT LINE. A SATELLITE CAMP WAS ESTABLISHED AT ROGER'S FLAT TO SUPPORT RESOURCES ASSIGNED ALONG THE NORTH FORK OF FEATHER RIVER. PERSONNEL EXPERIENCED AN EYE INJURY WHICH OCCURRED IN BASE CAMP.

21-Aug-00 TODAY'S FIRE ACTIVITY WAS NORMAL FOR A FIRE THIS SIZE AND WITH THESE BURNING CONDITIONS IN THIS TYPE OF TERRAIN. THE MAJORITY OF FIRE RUNS AND INCREASES IN ACREAGE ARE CAUSED BY BURNING MATERIAL THAT ROLLS DOWNHILL, STARTING A FIRE THAT THEN RUNS BACK UP THE SLOPES. GOOD PROGRESS CONTINUES TO BE MADE ON THE SOUTH END OF THE FIRE, INCLUDING BURNING OUT AND HOLDING OF INDIRECT LINE. A SATELLITE CAMP WAS ESTABLISHED AT ROGER'S FLAT TO SUPPORT RESOURCES ASSIGNED ALONG THE NORTH FORK OF FEATHER RIVER. THE CURRENT THREAT CONTINUES TO BE TO STRUCTURES IN 5 SMALL COMMUNITIES, POWERLINES, RAILROAD, AND THE PACIFIC GAS AND ELECTRIC POWERHOUSES.

22-Aug-00 Fire activity increased substantially late PM today with stronger winds and decreasing atmospheric stability. Torching, short runs, and spotting were observed in several areas. A spot fire occurred on the South side of the North Fork Feather River near the junction of highway 70 and Caribou road. It was detected when it was 1/4 acre. There was a 20 acre spot fire in Division V.

A slopover in division B required the use of air tankers. An additional spike camp was established at Snag Lake to support resources assigned on the NE flank. The incident has been divided into 4 branches at this time. Hwy 70 is open but subject to traffic control in areas where rock slides have been occurring. A protection group remains assigned at Base Camp/ICP.

23-Aug-00 The fire was active today but not to the extreme activity that was expected based on weather and fire behavior predictions. Torching, spotting, and short runs occurred after the inversion lifted around 1230 hours. The large spot fire in the Bucks Lake Wilderness continued to spread eastward towards Three Lakes as well as downslope. There were several spots across the Mosquito Creek drainage. Tonight's staffing includes 4 branches with a total of 18 divisions. Acreage and containment figures in this report are estimated because helicopter for mapping flight is not available. The acreage we report today includes 2,770 acres in the spot south of North Fork Feather River. Hwy 70 remains open through the day.

24-Aug-00 The fire was active today with stronger than expected winds. There were continued spotting problems near the fire's head. Burnout operations in Division C, T, and S are progressing successfully. Progress was made with indirect line construction and burnout to contain the large spot in the Bucks Lake Wilderness today. However, the fire has strong potential for lateral growth towards

Meadow Valley and to cross the East Branch, North Fork of the Feather River. Today's staffing includes 5 branches encompassing 15 divisions and 2 groups. Hwy 70 remains open to the public.

25-Aug-00 The fire was active in several locations today, most notably where firing operations are in progress on the north flank in divisions Q, R, and S and along the NE flank in Divisions C and D.

Spotting problems were again experienced at the fire's head. Branch V, south of the North Fork Feather River continued burning actively to the east, progressing to Kellog Ravine. Control lines on the west side of Branch V have now been mostly connected ("tied in") to control and areas burned by the Bucks Fire last year.

26-Aug-00 Fire activity has moderated today. However, the potential remains for spotting and significant runs.

On the main fire, most of today's activity was where firing operations have been in progress. Burnout is being conducted on the NW flank in Divisions Q and P and on the west flank in Division C. In the area south of the North Fork of the Feather River, lateral spread continues slowly to the east. Infrared imagery confirms that we have good progress with mop-up on the east flank. Tonight's staffing includes 5 branches encompassing 18 divisions and 3 groups.

27-Aug-00 The incident was more active than expected today with gusty winds in the afternoon. Spotting was a problem on the east flank with a 5-acre slopover around 1500 hours. The northwest flank remained active in areas where firing operations have been underway. Eastward spread continued in the Bucks Lake Wilderness. A crew from American Somoa checked in for assignment today. Staffing for tonight includes 4 branches with 8 divisions. Acreage in this report includes 3,828 ac. of private land and 34,592 acres on National Forest.

28-Aug-00 Indirect line continues on NE and W flanks of main fire ahead of 2 firing operations that meet at the head of Chips Creek drainage. An indirect strategy is being used to cut off the eastward spread of the fire portion that has passed through the Bucks Lake Wilderness. Good mop-up has enabled us to consolidate 4 divisions on S end of main fire, which is now in patrol status. Structure protection continues along highway 70 in the Rich Bar area. There were 2 reported injuries today. One was 1st and 2nd degree burns to a firefighter's lower leg from stepping in a stump hole. The second was to a firefighter's ankle and Achilles tendon. Staffing tonight includes 4 branches with a total of 6 divisions.

29-Aug-00 Indirect line construction continues along west and northwest flanks of main fire as crews hold and mop up areas previously burned out. Resources are still assigned for structure protection along Hwy 70 where fire from the Bucks Lake Wilderness continues spreading east and backing into the canyon bottom. An outbuilding, some lean-to structures, and miscellaneous private property burned today. Tonight's staffing includes 5 branches with 7 divisions.

30-Aug-00 Indirect line construction has been completed on the west and northwest flanks of the main fire. This includes approximately 2 miles of natural barrier (a high elevation area mostly devoid of vegetation) between Lotts Lake and Morris Lake. Burning operations continue along these lines, and some interior burning using aerial ignition has been undertaken. Spotting remains a problem.

Helicopter water drops are being used to retard eastward progression of the "spot" fire which has burned through portions of Bucks Lake Wilderness. Structure protection remains a concern along Hwy 70.

31-Aug-00 There was moderate fire activity across the area today with cloud cover, decreased temperatures, and higher relative humidity. Aerial ignition of unburned interior fuels continues within indirect containment lines on both the main fire and portions of the "spot fire" below the North Fork of the Feather River. Helicopter bucket drops are still being used to prevent eastward spread of the "spot fire" from crossing Clear Creek (a wet drainage). Structure protection remains a concern along Hwy 70.

Aggressive mop-up continues in preparation for a possible wind event tomorrow.

01-Sep-00 The incident area received approximately 0.10" of rainfall during a 5 hour period today resulting in minimal fire activity. There will be no night shift this evening and limited line staffing tomorrow to avoid road damage and the potential for vehicle accidents.

Base Camp will be relocated to the fairgrounds in Quincy, California tomorrow, 09/02/2000.

02-Sep-00 The incident area received rain last night and today, resulting in minimal fire activity. There will be no night shift this evening and limited line staffing tomorrow to avoid road damage and the potential for vehicle accidents. No aircraft was used today.

03-Sep-00 Today's fire activity was again minimal with the perimeter remaining static. There will be no night staffing tonight. Increased staffing is planned for day shift tomorrow as road conditions continue to improve.

Percent containment has been adjusted to reflect increased confidence that indirect line will hold on the west flank of the main fire.

04-Sep-00 Continued low levels of fire activity are expected throughout the evening.

05-Sep-00 Continued low levels of fire activity are expected throughout the evening.

06-Sep-00 Continued low levels of fire activity are expected throughout the evening. Fire suppression rehabilitation is being coordinated with local experts in resource management, and implementation continues.

07-Sep-00 Continued low levels of fire activity are expected throughout the evening.

08-Sep-00 Continued low levels of fire activity are expected throughout the evening. Fire activity remains minimal and confined to hot-spot areas. Suppression activities are in the mop-up stage during daylight hours. Fire suppression rehabilitation is being coordinated with local resource advisors and implementation continues. Suppression and rehabilitation objectives are being met.

10-Sep-00 Continued low levels of fire activity are expected throughout the evening. Fire activity remains minimal and confined to hot-spot areas. Suppression activities are in the mop-up stage during daylight hours. Fire suppression rehabilitation is being coordinated with local experts in resource management, and implementation continues. Suppression and rehabilitation objectives are being met.

11-Sep-00 Continued low levels of fire activity are expected throughout the evening. Fire activity remains minimal and confined to hot-spot areas. Suppression activities are in the mop-up stage during daylight hours. Fire suppression rehabilitation is being coordinated with local experts in resource management, and implementation continues. Suppression and rehabilitation objectives are being met.

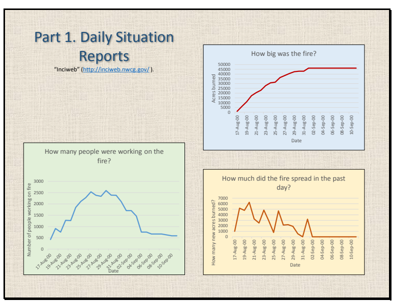
Slides and Narrative for *StorrieFire&ClimateChangeData_MiddleSchool.pptx*

Slide 1

Slide 2

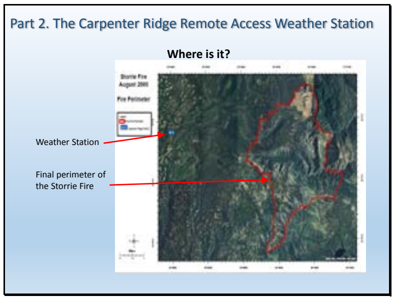
Part 1 contains information about the Storrie Fire. This slide shows an excerpt from the fire managers' journals (part of the "Daily Situation Reports") for the fire. All of the journal entries in a separate document – Handout M08-2. *Storrie Narrative.docx*. You'll need to read the journal entries so you can pick a date for your podcast.

Slide 3



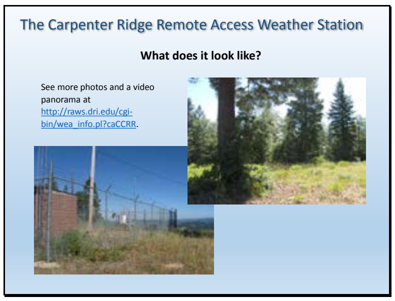
Here is information on the Storrie Fire's size each day, how many people were working on it, and how much it grew in the previous 24 hours. This information is taken from the Daily Situation Reports. While the Situation Report showed the fire's size as about 45,000 acres, the fire was mapped carefully after it ended, and the results showed that it eventually burned 56,060 acres.

Slide 4



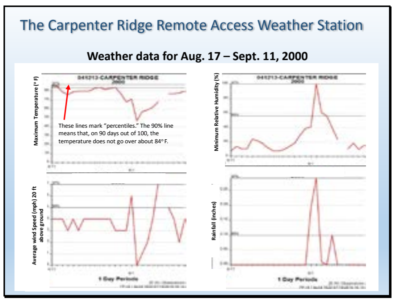
For your podcast, you will need information on weather conditions during the Storrie Fire. The next few slides show weather conditions during the time of the fire, but these records are not from the actual location of the fire; they are from a remote access weather station a few miles away. (Remote Access Weather Station means that the station is operated electronically – not by people. Weather conditions are measured automatically at about 1 pm each day, and the data are transmitted by satellite to a recording center.

Slide 5



Here are some photos of the weather station.

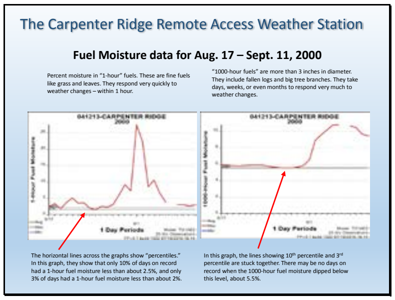
Slide 6



Here are records of maximum temperature, minimum relative humidity, average wind speed, and rainfall for each day. The red arrow points to percentile lines; they are explained in the text connected to the arrow.

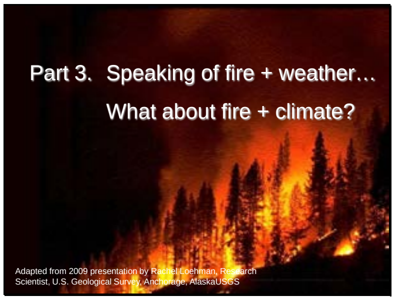
The wind speed in the lower left graph is not the average for ALL DAY; it is the average of the measurements taken in the 10 minutes before "transmit time" each day. That is the time when the previous 24 hours' weather is transmitted by satellite to the National Weather Service, around 1 pm.

Slide 7



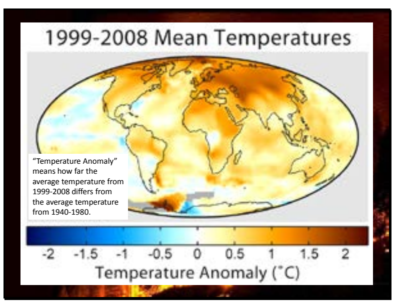
Here are records of fuel moistures during the time of the Storrie Fire. Again, the red arrows point to percentile lines, and these are explained below the graphs.

Slide 8



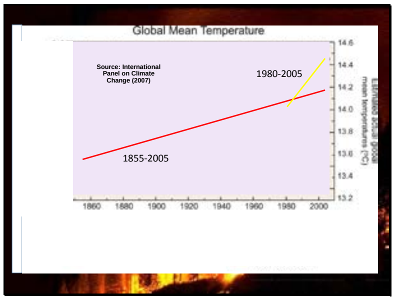
The slides in Part 3 have information about climate and how things have changed in the past century or two. You will some of this information so your podcast can answer the question, "Is it possible that some places in the world, including the Sierra Nevada, might see more fires like the Storrie Fire because of global climate change?" (This is Question #3 in the assignment.)

Slide 9



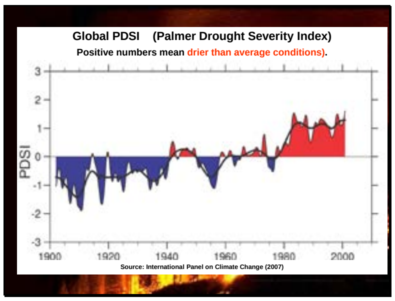
This figure shows the difference in the earth's surface temperatures between January 1999 and December 2008 and "normal" temperatures at the same locations. "Normal" temperatures are defined as the average over the interval January 1940 to December 1980. This graph shows an average increase of 0.48 °C. These widespread temperature increases are considered to be an aspect of global warming.

Slide 10



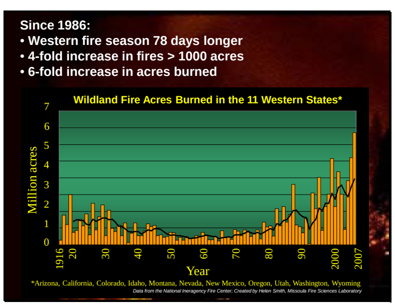
This graph has two lines. The long red line shows the trend in global average temperatures from 1855 to 2005, a period of 150 years. The short yellow line shows the trend in global average temperatures from 1980 to 2005, a period of 15 years. You may want to use this information in your podcast as you discuss whether global climate change is affecting wildland fires.

Slide 11



This graph shows trends over the last 220 years in the Palmer Drought Severity Index (PDSI). This index uses temperature and precipitation data to estimate dryness. Its scale is not a measurement but instead an "index" that goes from -10 (driest) to +10 (wettest). The PDSI has been reasonably successful at quantifying long-term drought conditions (https://climatedataguide.ucar.edu/climate-data/palmer-drought-severity-index-pdsi). Perhaps you will want to use this information in your podcast to talk about possible connections between climate change and wildland fire.

Slide 12



This graph shows how much area burned in 11 states of the American West from 1916 to 2007. You may want to use this information in your podcast as you talk about possible connections between climate change and wildland fire.

Unit IV.
Fire Effects on the Environment

Unit IV brings students' attention to the effects of wildland fires on non-living parts of the ecosystem: air (Activity 9), and soil and water (Activity 10).


2010 Eagle Trail Fire, Tok, AK, by Larry Walsh (inciweb.nwcg.gov)

9. Smoke from Wildland Fire: Just Hanging Around?

Subjects: Science, Mathematics, Reading, Writing, Speaking and Listening, Social Studies, Health Enhancement

Duration: One to two half-hour sessions

Group size: Entire class

Setting: Classroom

New FireWorks vocabulary: *inversion, particulate/particulate matter, PM10/PM2.5, smoke, stable/unstable atmospheric conditions, visibility*

Lesson Overview: In this activity, students learn that smoke from wildland fires can either disperse readily or stick around, reducing visibility on the earth's surface and making it difficult to breathe. From a demonstration, they learn that long-term smoke episodes caused by inversions can be very harmful to human health – even though the smoke may benefit some plants. Finally, students they apply health guidelines regarding smoke to the problem of scheduling athletic practices on a smoky day.

Lesson Goal: Increase students' understanding of smoke from wildland fires, how it disperses, and its effects on ecosystems on human health.

Objectives:

- Students can interpret information about air quality, dispersion, and visibility during a wildland fire.
- Students can recommend measures for protecting their own respiratory health and that of others.

Standards:		6th	7th	8th
CCSS	Speaking and Listening	1,2,4,5	1,2,4,5	1,2,4,5
	Language	1,3,6	1,3,6	1,3,6
NGSS	Weather and Climate	ESS2.D		
	Earth's Systems	ESS3.A		
	Human Impacts	ESS3.B,C		
EEEGL	Strand 1	B, C, E, F, G		

Teacher Background: There's no wildland fire without smoke, but the amount of smoke produced and the way in which it disperses differ from one fire to another and from one time to another on a single fire. If the smoke disperses upward rapidly, high-altitude winds will scatter it downwind, and the only result we notice may be the beautiful, orange-tinged sunrise and sunset colors produced by particles in the air. However, if the smoke is trapped near the fire by an inversion, it can make the air difficult to breathe and even difficult to see through. These conditions benefit some plants by increasing seed germination. For humans, however, they are hazardous, especially for anyone who has asthma or other respiratory illness and for those who engage in strenuous exercise.

In this activity, students learn that smoke can disperse readily or be trapped by an inversion. Then they consider who might benefit from smoke and who might be damaged by it. Finally, they use data on visibility and particulate matter to decide if and when smoke from a wildland fire may be hazardous to their health.

On most summer days, sunlight warms the earth's surface each morning, and the air lying on the earth's surface is heated too. This warming, expanding air rises, and its temperature decreases due to the expansion. If the air is dry, the temperature falls about 1°C for every 100-meter rise in altitude. As a result of this natural cooling, mountain tops tend to remain much cooler than valleys even on hot summer days. Because the air is constantly moving and mixing under these circumstances, we call it unstable.

Sometimes the sun doesn't warm the earth's surface very much during the day. Clouds may block the incoming sunlight. In winter, the ground may be covered with snow that reflects sunlight instead of absorbing its energy. In summer, the smoke from a fire may be too dense to let sunlight through. When this happens, the cold air is stuck on the ground, and a warm layer of air rests on top of it. It is not expanding, therefore not rising, and therefore it is "trapped" on the ground until something stirs up the atmosphere. This is called an inversion because the normal daytime pattern (warm air on the bottom, cool air on top) is upside-down. The blanket of warm air lying on top of the cold air is called the inversion layer. During an inversion, the cold surface air is very stable. It cannot be dislodged until it is heated or stirred up by wind.

During an inversion, dust and other particulates in the air are trapped in the cold air at the earth's surface. Inversions during wildland fires trap smoke, which may be so dense that you can't see very far and the city streetlights come on in the middle of the day. When seeds of some plants are exposed to dense smoke, it becomes easier for them to germinate. But when people are exposed to dense smoke, it becomes harder to breathe. Dense smoke is especially dangerous for babies and anyone with asthma or other respiratory illness. It is a good idea for some types of seeds to be outdoors during a smoke-filled inversion, but it is a good idea for people to limit aerobic activities and even stay indoors until the air quality improves.

Materials and preparation:

- Download PowerPoint ***M09-1_SmokeAndHealth.pptx***
- Make 1 copy/student of **Handout E07-1: Cancel a Sports Event?**
- Find these in the trunk or your lab supplies:
    - Two 1-qt freezer contains or two 500-ml beakers
    - Digital thermometer with thermocouple wire. Make sure the thermometer's battery works. Have a spare on hand.
- On the day before the activity, fill one of the containers half full with water and freeze it. If you forget, use ice cubes.

- On the day of the activity, have boiling water ready to fill the other container half-way. Keep it hot until you need it.
- Set up your lab bench or demonstration table with the container of ice on the right side (facing the class) and the empty container on the left. Make two signs ("Ice cold" and "Boiling"), and place them next to the appropriate containers. Place the digital thermometer and boiling water on the table too.
- Write the following table on the board or project it:

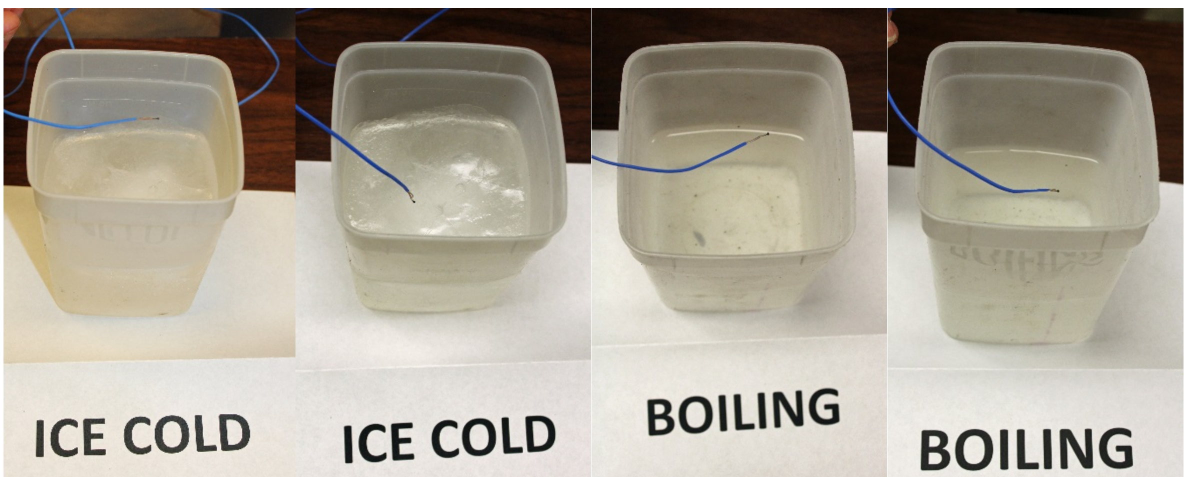
Classroom temperature (°C):		
	Ice	Boiling water
Temperature °C, level with top of container		
Temperature °C, inside container, 0.1 cm above ice or water		
Is air right above ice/water warmer or colder than air above?		
Describe the movement of the air right above the ice/water surface:		
Air above the water: stable or unstable?		
Inversion present?		

Procedures:

1. **Hook:** Select 3-4 students to sit in a circle around a prop (box, book, stool, other object) that represents a campfire. Have them pantomime some fun things to do. Maybe they'll start a song, roast marshmallows, add sticks to the fire, etc. Then have another student be wind and circulate around the fire or back and forth, blowing on the smoke. Ask those sitting around the fire to react. As they cough and hack or move to a different spot, ask what the problem is. SMOKE BOTHERS US!
2. Ask: What is smoke? Smoke consists of water, gases, and tiny particles of unburned and partially burned fuels. These are called *particulates* or *particulate matter*. The particulates are light enough to circulate in the atmosphere instead of settling immediately to earth, as larger particles do.
3. Explain: In this class, we'll learn about where the smoke from wildland fires goes.
4. Project PowerPoint *M09-1_SmokeAndHealth.pptx* – **ONLY SLIDES 1-4,** which illustrate where smoke goes and how it can hang around for days or even weeks. (Use the handout and narrative shown at the end of this activity.)
5. **Stop the slides and start the lab demonstration.** Explain: To understand how smoke moves around, we have to understand the daily movement of air. Every day, sunlight reaches the earth's surface, heats it up, and then heats the air next to it. Every night, the earth cools off because the sun isn't heating it anymore, and the surface air cools off too. We're going to

investigate how air behaves – how it moves around – above hot and cold surfaces. This will help us understand how smoke behaves.

6. Get 3 students to help with the demonstration and begin:
   a. Have one student turn on the digital thermometer and hold its display up so the class can see it. Measure in degrees C.
   b. Have another student hold the thermocouple tip at shoulder level. Have the class call out the temperature, discussing until they agree on it.
   c. Have a third student record that temperature in the top row of the table on the board.
   d. In the “ice” container, have students measure and record temperatures at these 2 locations:
      - Level with top of container, over its center (see photos)
      - Inside container, about 1 mm above surface of ice (not touching ice/water). If the thermocouple touches the ice/water, you’ll know because the temperature will changes very fast. Just dry it off and try again.



   e. In the “boiling” container, do the same thing. (It may be hard for the class to decide what the temperatures really are because the air above the water should be very turbulent. That’s OK.)
   f. Now complete the table. See the example below.
      - For each container, is the temperature 1 mm above the ice/water “warmer” or “colder” than the temperature at the top of the container?
      - How would you describe what the air is doing above the two surfaces? Use pairs of “contrast” words, such as *quiet* vs. *wild, still* vs. *busy, unmoving* vs. *moving, or peaceful vs. turbulent*.

- For each container, would you call the air above the ice/water surface *stable* or *unstable*?
- Explain: If the air is stable, there is an *inversion* present. That is, the usual pattern of warm air on the bottom and cooler air on top is now upside-down, trapping the cold air at the bottom. That's how smoke can get stuck and make the air murky and hard to breathe. The same thing can happen with dust and automobile exhaust on winter days.

Here is an example of the information that should be in the table when you're done:

Classroom temperature (°C): 20		
	Ice	Boiling water
°C, level with top of container	19	25
°C, inside container, 1 mm above ice or water	7	83
Is the air right above ice/water surface warmer or colder than air above?	colder	warmer
Describe the movement of the air right above the ice/water surface:	still dull peaceful etc.	wild crazy turbulent etc.
Air right above the water: stable or unstable?	stable	unstable
Inversion present?	yes	no

g. Ask: What conditions might keep the surface air from rising and thus create an inversion? Clouds may block the incoming sunlight. In winter, the ground may be covered with snow that reflects sunlight instead of absorbing it. In summer, the smoke from a fire may be too dense to let sunlight through.

h. Review and summarize: Air heated by the earth's surface rises and is constantly replaced by cool air flowing down from higher elevations. These forces keep the air in motion, so we call the atmosphere *unstable*. If the earth's surface is too cold to heat the air on the ground, the dense valley-bottom air cannot rise; it is trapped. Then we call the atmosphere *stable*, because air will not begin moving until the surface air warms up or is disturbed by wind. We call this condition an *inversion*, because the usual temperature gradient (warm below, cold above) is upside-down.

7. **Return to** PowerPoint ***M09-1_SmokeAndHealth.pptx,*** **slides 5-11**, which illustrate the effect of smoke on visibility. They show a single viewpoint with different amounts of smoke.
   - Slide 6 explains the metric used to measure air quality: micrograms/cubic meter ($\mu g/m^3$) is the weight of smoke particulates of a certain size (and smaller) in a specific volume of air. PM10 is the weight of particulates 10 micrometers across or smaller. PM2.5, which students will use in the assessment, is the weight of particulates 2.5 micrometers across or smaller.

- Slide 11 is a summary of slides 5-10. It shows the changes in visibility with 5 vs. 90 $\mu g/m^3$ of PM10.

8. Ask: How does very smoky air affect us? It obviously reduces visibility, but it also gets into our lungs, where it interferes with our ability to absorb oxygen and release carbon dioxide – making it harder to breathe.

9. Ask what else may be affected by smoke. Students may say animals, soil, plants. When students mention plants, explain: Seeds can be affected by smoke. Some types of seeds *germinate* better after being exposed to smoke. In the western United States, several plants have *dormant* seeds that germinate more readily after being exposed to smoke. Examples include big sagebrush, antelope bitterbrush, and basin wildrye. Other plants that germinate well after smoke include 2 garden vegetables - lettuce and celery. Scientists don't know the exact reasons why some plants germinate well after exposure to smoke.

10. Explain: While smoke might be good for some seeds, it's not good for us. Medical experts have provided guidelines for outdoor recreation to help us humans protect our lungs from smoke. Give each student a copy of **Handout M09-1: Cancel a Sports Event?**

11. Have students read the guidelines on the handout. Discuss how the air quality in the final photo of the PowerPoint presentation would be rated ("very unhealthy," since you can faintly see the ridge 7 km away, and the peak 17 km away has almost disappeared). Decide together if plans for various sports events should be changed. Include indoor as well as outdoor sports so they get the idea that indoor sports need not be restricted.

Assessment:

1. Pair off. One of you be the school nurse, the other be a coach for a sports team. (You get to pick the sport.) You know that two members of the team have asthma. You look out the window together, and you can just barely see the top of a hill 7 kilometers away. Talk the situation over and decide what to do about today's after-school practice. Make sure you decide if your asthmatic team members should do anything differently from the rest of the team.

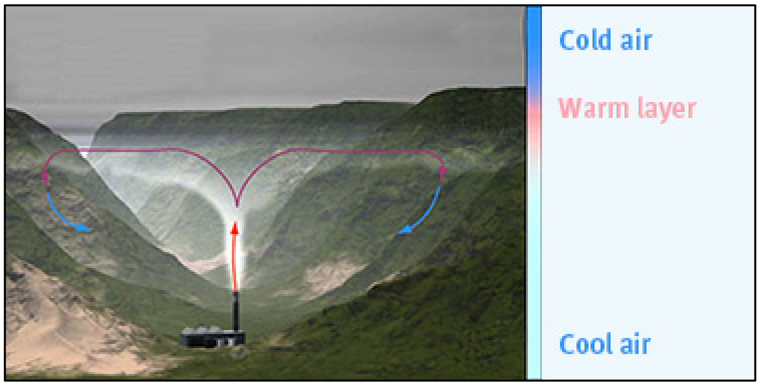
2. Together, report to the class:

    - what sport you were discussing
    - what activity levels the handout recommends for the amount of smoke in the air
    - what you decided to do about practice and why – including any special instructions for students with asthma

Evaluation:

Full Credit	Partial Credit	Less than Partial Credit
-Students identified the sport they discussed and whether it is indoor (like swimming or basketball – and not likely to be affected by smoke) or outdoor. -Students used recommendation from handout to explain that visibility of 7 km fits in the **unhealthy** health effect category -Students decided to postpone or delay or shorten time for outdoor practice or to move practice indoors, and students decided that athletes with asthma would not participate in outdoors practice.	-Students identified the sport they discussed -Students used recommendations from handout but used the wrong health effect category or did not show understanding of health effects of smoke. -Students made appropriate decisions for the health effect category chosen but did not identify special instructions for athletes with asthma.	-Students identified the sport they discussed -Students did not use recommendations from handout. -Students did not indicate a general understanding of the correlation between sports practice, smoke levels, and health.

Handout M09-1: Cancel a Sports Event?



This diagram shows pollutants from an industrial smokestack being trapped by an inversion (from https://www.qld.gov.au/environment/pollution/monitoring/air-monitoring/meteorology-inversions/).

Recommendations for Sports Events during Wildfires[9]

Health Effect Category	µg/m³ of PM10 or PM2.5	Visibility*	Recommendation
Good	Up to 19	21 km or more	Hold outdoor sporting events as usual. Athletes with asthma should keep rescue inhalers handy.
Moderate	19 to 51	8 to 21 km	Hold outdoor sporting events as usual, but athletes with asthma or other respiratory illness should limit outdoor activity and stop if they start having trouble breathing.
Unhealthy	51 to 115	3.5 to 8 km	Consider postponing outdoor sporting events, especially high exertion activities like soccer and track field. If possible, move practice indoors.
Very unhealthy	115 to 195	2 to 3.5 km	Consider postponing all outdoor sporting events. Move all practices indoors. Everyone should avoid prolonged outdoor exercise.
Hazardous	More than 195	Less than 2 km	Cancel all outdoor sporting events or relocate indoors. Move all athletic practices indoors.

*Visibility: How far can you see? To figure this out:

1. Face away from the sun.
2. Look for landmarks at a known distance from you.
3. If you can't see a landmark, then you know that visibility is less than that distance.

[9] Based on "Decision making recommendations during wildfire season for Outdoor Sporting Events" and "Draft Missoula County Wildfire Smoke Emergency Episode Avoidance Plan" dated 7/20/2009, by the Missoula City-County Health Department, Missoula, Montana (http://www.co.missoula.mt.us/airquality/pdfs/2009EEAP.pdf). These guidelines are adapted from more general ones provided by the National Incident Information System (http://inciweb.nwcg.gov/photos/OKCHP/2014-12-21-0939-Chickasaw-NRA-RXfy2015/picts/2015_01_22-08.19.09.768-CST.pdf).

Slides and notes for PowerPoint *M09-1_SmokeAndHealth.pptx*

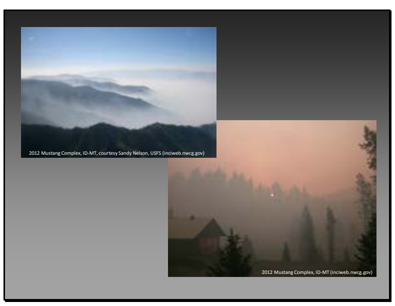
Slide 1

We've measured the shape of the heat plume from small fires, and we've watched the smoke from our classroom experimental fires. Here are photos of smoke from wildland fires. Where does the smoke usually go? (Up, and then in the same direction as the wind. It also stays around the base of the fire where it is being produced.)

Slide 2

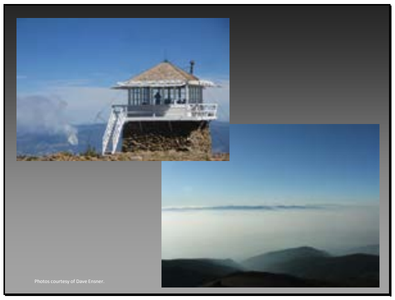
Smoke doesn't just disappear into the air. Satellite photos show that it can travel a long way. Discussion: Use the 25-km scale on the left photo to figure out how wide the smoke plume is (50-75 km) and how far it has traveled (at least 300 km). Think of some towns or other landmarks that are that far away.

Slide 3



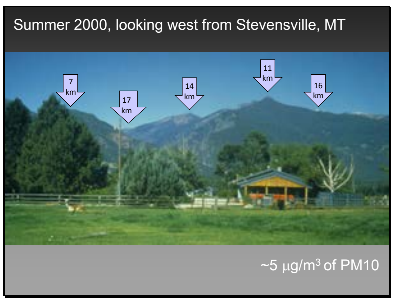
Smoke sometimes settles down near the ground and stays there for days or even weeks. This might be smoke from a fire nearby, or it could be smoke from fires hundreds of miles away.

Slide 4



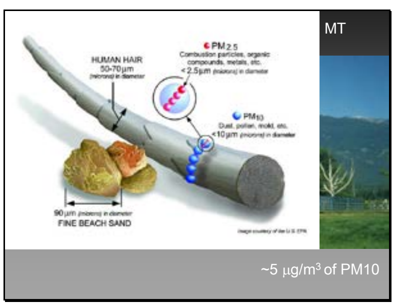
Here are two contrasting views, looking eastward from St. Mary Lookout, Bitterroot National Forest, MT. Top: Summer 2013. Smoke disperses upward from a fire in the valley, then drifts northward. Bottom: Smoke has settled into the valley overnight. Now it keeps sunlight from reaching the valley floor, so the air above the smoke layer is warmer than in the valley. The smoke is trapped in the cold, heavy, dense valley air.

Slide 5



Let's see how smoke can affect visibility. The arrows show how far away various mountain and ridge tops are.

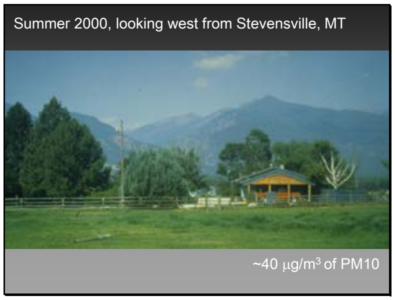
Slide 6



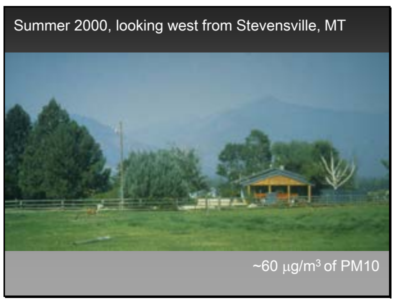
What is that number at the bottom of the slide – ~5 micrograms/m^3 of PM10 ? It is a way of measuring the concentration of particulates in the air and is read "micrograms per cubic meter of particles less than 10 micrometers in diameter". Whew! That's a long name for a very, very small thing. This diagram shows how big 10 micrometers are in relationship to the size of a human hair. We use PM2.5 (particles less than 2.5 micrometers in diameter) more often than PM10 because the smaller particles, though less visible, cause more damage to human lungs.

Slide 7

Slide 8



Slide 9

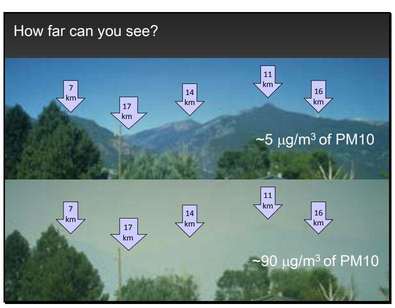


The farthest mountains have nearly disappeared.

Slide 10

Now the far mountains have completely disappeared, and the near ones are very hard to see.

Slide 11



The arrows show how far away the mountains and ridges are in clean air and unhealthy air.

10. Fire, Soil, and Water Interactions

Lesson Overview: In this activity, students view and take notes on a presentation. Then they either observe or conduct an experiment that illustrates how wildland fires affect the potential for soil erosion. They learn that *soil burn severity* varies greatly and that when fires remove the litter, duff, and plant cover on the ground, the risk of soil erosion increases.

Lesson Goal: Increase students' understanding of the effects of wildland fire on soil properties and the likelihood of erosion after fire.

Subjects: Science, Mathematics, Reading, Writing, Speaking and Listening, Health Enhancement

Duration: One half-hour session

Group size: Entire class

Setting: Classroom

New FireWorks vocabulary: *burn severity, erosion, litter, soil burn severity, vegetation burn severity*

Before beginning this lesson, watch the video demonstration of precipitation's impact on bare soil versus vegetation-covered soil: https://www.youtube.com/watch?v=im4HVXMGI68. Decide if you want to do the demonstration in class or just view the video. If you decide to do the demonstration in class, you need a container containing young grass stems that were started from seed 2-4 weeks before. You may be able to use a cut piece of sod instead.

Objectives:

- Students understand how fires affect the soil.
- Students understand that the effects of fire on soils are variable.
- Students understand that if fires consume the litter, duff, and plant cover on the ground, this increases the chances of soil erosion.

Standards:		6th	7th	8th
CCSS	Writing Standards	4,10	4,10	4,10
	Speaking and Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Language Standards	1,2,4,6	1,2,4,6	1,2,4,6
	Writing: Science and Technology	4,10		
EEEGL	Strand 1	A,B,C,E,F,G		

Teacher Background: Soil burn severity is the degree of change of ground surface characteristics, including char depth, organic matter loss, altered color and structure, and reduced infiltration, caused by fire.

After fire, common changes to the soil include:

- loss of ground cover due to consumption of litter and duff;
- surface color change due to char, ash cover, or soil oxidation;
- changes in soil structure due to consumption of soil organic matter;
- consumption of fine roots in the surface soil horizon; and
- formation of water repellent layers that reduce infiltration.

The degree of soil burn severity varies widely from fire to fire, and within individual burns. It depends on many factors, including the **weather** at the time of burning, fire behavior, the amount, type, and distribution of **fuels**, type of soil, and **slope**. Notice that the Fire Environment Triangle studied in Unit III covers many of these factors.

The more severe fire's effects on the soil, the more likely those soils will erode in subsequent rainstorms – especially in places with steep slopes. Erosion after fires can cause tremendous damage to people's homes and other structures in the first year or two after a fire.

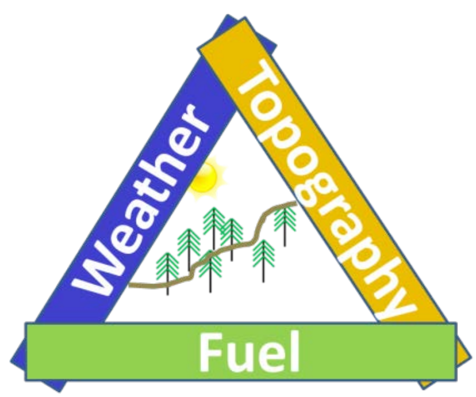
You can find more detailed information about fire and soils in PowerPoint *M10-1_FireSoilAndWater.pptx*, the presentation used in this activity.

Consider doing **Activity M15 (Bark and Soil: Nature's Insulators)** to learn about heat transfer in the soil under a protective layer of duff.

Source and additional reading:

Parsons, Annette; Robichaud, Peter R.; Lewis, Sarah A.; Napper, Carolyn; Clark, Jess T. 2010. Field guide for mapping post-fire soil burn severity. Gen. Tech. Rep. RMRS-GTR-243. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 49 p. http://www.treesearch.fs.fed.us/pubs/36236

Materials and preparation:



1. Display the Fire Environment Triangle poster (***FireEnvironmentTriangle.pdf***).
2. One copy of **Handout M10-1. Fire and Soil** per student.
3. Download and view PowerPoint ***M10-1_FireSoilAndWater.pptx***. The notes for the presentation (shown below) are written to guide discussion and to prompt students to answer questions on their handout. On each slide:
   a. you introduce the new information;
   b. then you have students answer a question on the **Handout M10-1. Fire and Soil**;
   c. then you do a short follow-up discussion.

d. If you wish, you can then let students revise their answers on the handout.

4. View this video about the relationship between vegetation cover and soil erosion: https://www.youtube.com/watch?v=im4HVXMGI68 Decide whether you will watch the video in step 3 (below) OR do the activity that is shown in the video. If you do the activity, you will need:
   - Three empty-2 liter plastic soda bottles
   - Three empty plastic soda bottles (about 1 liter size)
   - Three pieces of string/yarn
   - Soil
   - Dead leaves/needles
   - Grass seed (planted in the soil a couple of weeks ahead of time)
   - Pitcher of water

Procedures:

1. Explain: Fires change more than the plants above ground; they change the soil too. Think about the three parts of the Fire Environment Triangle: fuels, weather, and topography. All of these things influence how fires affect soils. That's what we'll learn about today.

2. Explain: We'll start with a presentation that goes together with a handout. You'll answer 1 question on the handout for each slide in the presentation.

3. Give each student a copy of **Handout M10-1. Fire and Soil.**

4. Show PowerPoint ***M10-1_FireSoilAndWater.pptx****,* using the notes below and stopping for students to answer the question posed for each slide.

5. Either watch this video as a class: https://www.youtube.com/watch?v=im4HVXMGI68 OR do the activity in the video as a class.

Assessment: Handout M10-1. Fire and Soil.

Evaluation: See Handout M10-1_Fire and Soil_ Answer Key.

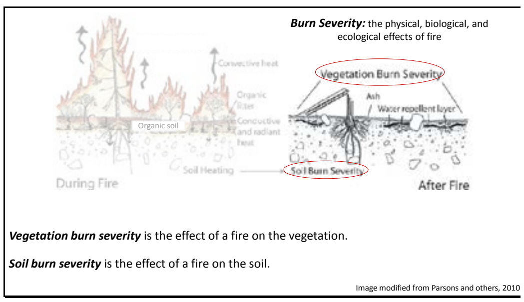
Slides and Notes for PowerPoint *M10-1_FireSoilAndWater.pptx*

Slide 1

This image shows where the heat from wildland fire goes. **Recall the 3 methods of heat transfer: convection, conduction, and radiation**. **Answer Question 1 on the handout.**

Discussion: Convection is lifting some of the fire's heat up, away from the soil. Conduction and radiation are transferring heat into the soil.

Slide 2

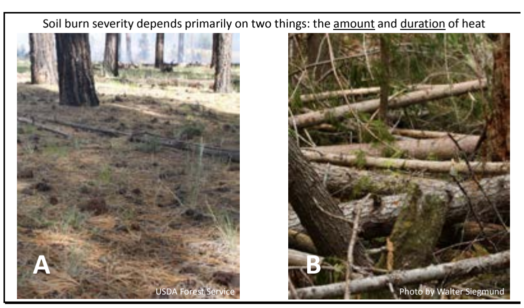


What does the heat from burning wildland fuels do to plants, ground cover, and soil after a fire? It depends on many things, so it varies! The physical, biological, and ecological effects of fire – all lumped together – are called *burn severity*.

Use this slide to answer Question 2 on the handout.

Discussion: In the right diagram, we can see the how the vegetation changed as a result of the fire. *Vegetation burn severity* describes the effects of a fire on vegetation. Vegetation burn severity is likely the first thing you notice when you look at burned forest, and we'll study it more in later lessons. But we can also see changes in the soil surface and even deep into the soil. This is *soil burn severity* - the effects of fire on the soil. That's what we'll study today.

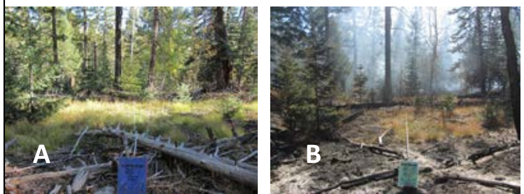
Slide 3



Soil burn severity depends mainly on 2 things: amount of heat and duration of heating. If a fire burned the surface fuels in these 2 photos under the same conditions, which fire would produce more heat? Which would burn for a longer time? **Answer Question 3 on the handout**

Discussion: Recall lesson M7 about fuel properties. The logs in the right photo would produce more heat and would burn longer. So it is likely that a fire burning the heavy fuels in the right photo would cause much higher soil burn severity than a fire in the pine litter in the left photo.

Slide 4



Before fire   After fire

Let’s look at soil burn severity in a small area – not much bigger than a classroom. The left photo shows this area before it was burned by a prescribed fire. The right photo shows what it looked like afterward. Look for diversity in soil burn severity. **Answer Question 4 on the handout.**

Discussion: Can you find patches that show no evidence of fire? How about patches that are “lightly burned” – that is, the ground surface is black and some woody fuels remain? How about patches that are “severely burned” – that is, the ash is completely white (no carbon left) and woody fuels are nearly gone? The lines of thick white ash, where the logs were before the fire, are places where the soil probably experienced hotter temperatures for longer periods of time than most of the other areas in this photo. That is, the areas underneath the logs experienced very high burn severity.

Slide 5


Video by Michael Yager

Here is a video of a fire moving though a forest. **Answer Question 5 on the handout.**

Discussion: Notice how the flames appear to be moving through the surface vegetation relatively quickly. If there is not much heavy fuel (like logs) underneath the vegetation, the soil may burn only lightly. Notice all of the heavy fuels from a previous fire. These include snags, stumps, and fallen logs. After the flames move through the vegetation, the logs and stumps will continue to flame and smolder, causing high soil burn severity in those spots.

Slide 6

This is a photo of that same fire. **Answer Question 6 on the handout.**

Discussion: You can see how the flames are concentrated in stumps and logs. In the foreground, the fire is actively spreading forward. The flames have gone out in many patches behind the flaming front. Where the fire has gone out, those areas will probably have low soil burn severity. In the background, flames are still burning in some stumps and logs. Those patches will probably have high soil burn severity.

Slide 7

Soil burn severity varies greatly even over small areas within a fire. Which areas of soil do you think burned most severely? Which areas burned less severely? **Answer Question 7 on the handout.**

Discussion:

- You can see lightly burned surface and ground fuels on the back-left side of this photo. Chances are the soil experienced low or moderate burn severity.
- In the middle of the photo, you can see areas of white ash and no remaining stems of small trees or shrubs. Underneath some of these white ash patches may be patches of severely burned soil.
- In the very foreground, it looks like some of the surface fuels aren't completely consumed, so maybe the soil was only moderately burned.
- In the middle, you can see lines where logs have been completely consumed, leaving nothing but white ash. These areas likely have severely burned soil beneath.

You may want to mention that, just because the vegetation appears severely burned, the soil may not be and vice-versa (i.e., vegetation burn severity does not equal soil burn severity). How could that happen? It could be caused by variation in soil composition, texture, moisture content, or other factors.

Slide 8

Both of these photos show places where most of the vegetation and ground cover has burned away. The soil does not have any protection from raindrops. **Answer Question 8 on the handout.**

Discussion: Loss of ground cover is the aspect of soil burn severity that is most likely to increase soil erosion and runoff. If there is no litter, duff, or plant cover and roots to hold the soil in place after fire, the soil is vulnerable to washing away especially after heavy rains.

Slide 9

In the corner, you can see the splash from a single raindrop. What happens when lots of rain falls on an area with severely burned soils? What if the area is on a steep hillside? **Answer Question 9 on the handout.**

Discussion: Areas with severely burned soils on steep slopes are the most vulnerable to erosion. Sometimes heavy rain on these soils causes big mudslides.

Slide 10

This photo is on your handout.

Use what you have learned in this activity to answer Question 10 on the handout.

Handout M10-1. Fire and Soil

Name: ____________________

1. What 2 forms of heat transfer move heat down into the soil?

2. Write the definition of each term:
   a. Vegetation burn severity:

   b. Soil burn severity:

3. Which photo shows a place that is likely to experience high soil burn severity? Why?

4. Describe the soil burn severity in the photo on the right (B).

5. What places in the video will probably experience low burn severity? Why?

6. After the flames have passed, what fuels are likely to keep on burning and producing heat?

7. In the photo, circle and label an area likely to have:
   a. *low soil burn severity*
   b. *high soil burn severity*

8. What is likely to happen if it rains after a fire has removed all of the litter, duff, and plant cover from the soil?

9. After a fire, what kinds of places are most likely to have severe erosion?

10. In the photo, circle and label 3 areas:
    a. A place likely to have high soil burn severity
    b. A place likely to have low soil burn severity
    c. A place that is likely to have severe erosion

Handout M10-1: Fire and Soil_ Answer key

1. What 2 forms of heat transfer move heat down into the soil? Conduction and radiation.

2. Write the definition of each term:
   c. Vegetation burn severity: the effect of a fire on the vegetation
   d. Soil burn severity: the effect of a fire on the soil

3. Which photo shows a place that is likely to experience high soil burn severity? Why? The photo on the right (B) has a lot of large, heavy fuels. They would produce more heat and burn for longer time (if they were ignited) than the fuels in photo A. The amount of heat and the duration of heating affect soil burn severity.

4. Describe the soil burn severity in the photo on the right (B). Soil burn severity varies a lot. In some areas, the forest floor is unburned. Some areas look lightly burned, and some areas look severely burned.

5. What places in the video will probably experience low soil burn severity? Why? Places without a lot of big fuels will probably experience low soil burn severity because the flames will pass through quickly and not burn very long.

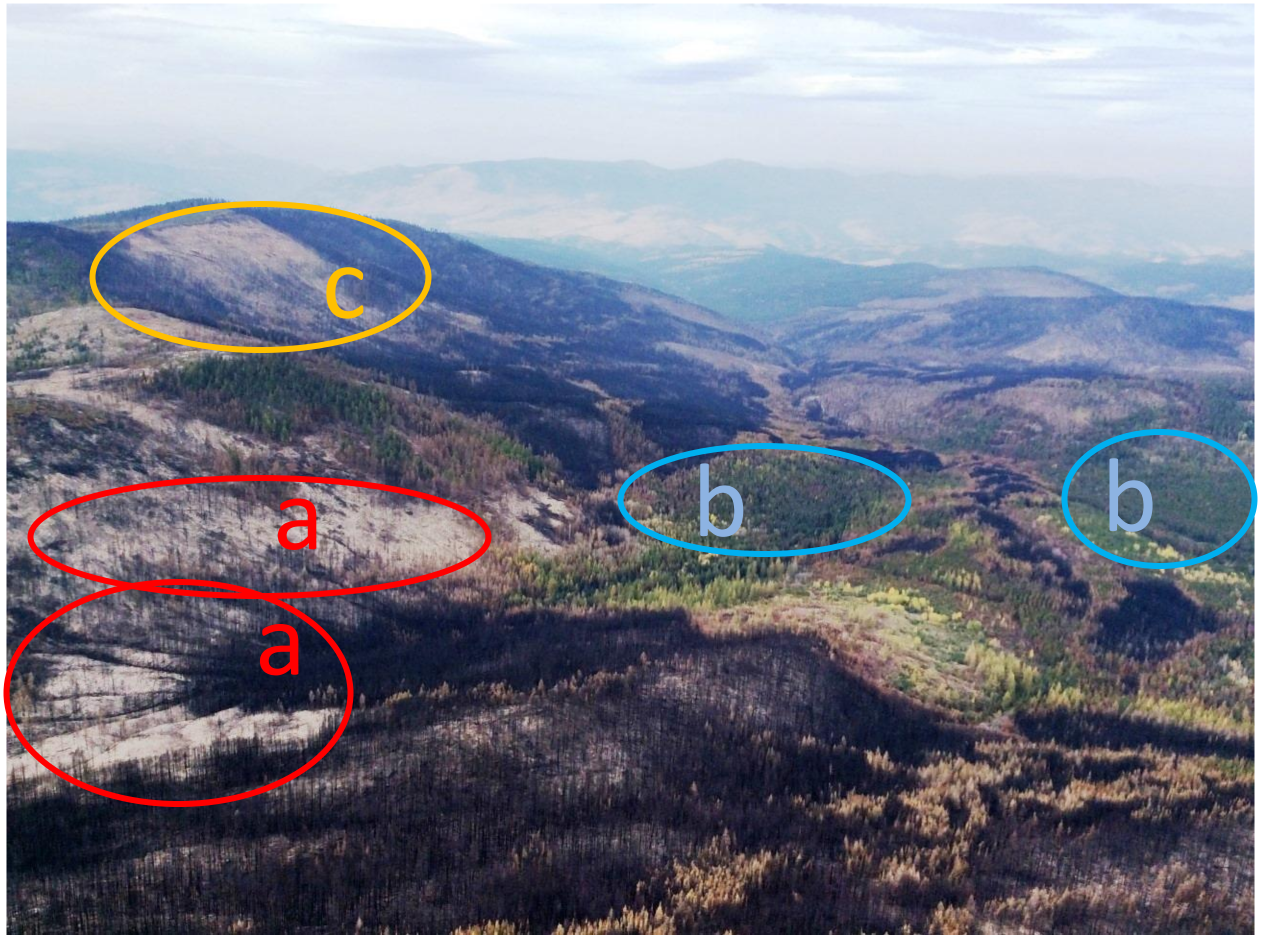
6. After the flames have passed, what fuels are likely to keep on burning and producing heat? Large fuels like stumps and logs.

7. In the photo, circle and label an area likely to have:
   a. *low soil burn severity*
   Blue circle is an example - the fire burned around or under small trees without burning their foliage, and the ash is black.
   b. *high soil burn severity*
   Red circle is an example - the fallen logs have burned and the ash around them is white.

8. What is likely to happen if it rains after a fire has removed all of the litter, duff, and plant cover from the soil? If there is no litter, duff, or plant cover to hold the soil in place, the soil is vulnerable to *erode* (wash away), especially after heavy rains.

9. After a fire, what kinds of places are most likely to have severe erosion? Areas on steep slopes with severely burned soils are the most vulnerable to erosion.

10. In the photo, circle and label 2 areas:
    a. A place that is likely to have high soil burn severity and high risk of erosion
    b. A place that is likely to have low burn severity and low risk of erosion
    c. A place likely to have <u>very high</u> risk of erosion because of it has high soil burn severity and is on a steep hillside.



Red circles indicate areas that likely have high soil burn severity. They all have high risk of soil erosion, especially the one at the top because it seems to have the steepest slope.
Blue circles indicate areas that likely have low soil burn severity. In this picture it is difficult to tell if these green patches of forest are unburned or experienced a surface fire and have surviving trees in the canopy. These areas are at low risk for erosion because they are relatively flat and likely have something covering the forest floor (litter, duff, live plants).

Unit V. Fire's Relationship with Communities

Having studied Units I-IV, students are now well informed about combustion, wildland fire behavior, fuels, and fire effects on nonliving parts of the ecosystem. In this unit, they will integrate their knowledge of fire with knowledge about living things, that is, specific organisms that live in montane ecosystems of the Sierra Nevada. They will learn about specific plants, animals, and fungi and the characteristics that help them survive fire or reproduce successfully after fire. They will use technical terms about tree morphology to identify several tree species in the Sierra Nevada, and they will learn how different assemblages of tree species are used to describe different forest communities. They will conduct an experiment to learn about the rates of heat transfer through various layers of insulation which, in nature, could be tree bark or soil.

11. Who Lives Here? Adopting a Plant, Animal, or Fungus

Overview: This activity introduces a suite of organisms that live in lower and upper montane forests and shrublands (*chaparral*) of the Sierra Nevada. Each student “adopts” an organism, learns about its characteristics and its relationship to fire, and gives a 3- to 5-minute presentation on it to the class – complete with a mask, costume, or puppet. (Alternative media include poster, computer presentation, or written abstract for adult audience.)

Goal: Increase students’ understanding of ecological communities, ecosystems, and biodiversity by learning about some of the plants, animals, and fungi that live in forests and shrublands of the Sierra Nevada.

Subjects: Science, Reading, Writing, Speaking and Listening

Duration: 1-2 class periods for student preparation, 3-5 minutes each for presentations

Group size: Whole class

Setting: Classroom

New FireWorks vocabulary: *biodiversity, chaparral, montane (lower and upper), organism*

Objectives:

- Students can prepare a mask, costume, or puppet (or use other media) and then give a 3- to 5-minute presentation (or prepare a poster or computer presentation) to the class that describes the biology of their “character” and its relationship to fire.
- Students understand that individual species have specific habitat needs and ways to survive the fires that are typical of the ecosystems where they live.

ABOUT SCHEDULING PRESENTATIONS: It may be helpful to spread presentations out over several class periods, 2-3 at a time. Make sure they are done by the time you get to **Activity M19**, in which the students will role-play to show the processes of fire and succession in these communities.

If you plan to do **Activity M15. Bark and Soil: Nature’s Insulators**, consider scheduling the presentations on tree species right before that activity – perhaps as an introduction to it. That way, students can easily connect the idea that thick bark might protect a tree’s cambium from fire with traits of particular species that they have been studying. If you plan to do **Activity M18. Fire History 2: History of Stand Replacing Fire**, save the presentation on Baker cypress for that one.

If you plan to do Activity **M16. Buried Treasures: Identifying Plants by their Underground Parts**, consider scheduling the presentations on shrubs and herbs right before it – perhaps as an introduction. That way, students can connect the importance of underground plant parts for regeneration to traits of particular species. The presentation on quaking aspen would fit well here too.

Standards:		6th	7th	8th
CCSS	Reading Informational Texts	1,2,4,7,10	1,2,4,7,10	1,2,4,7,10
	Speaking and Listening	1,2,4,5,6	1,2,4,5,6	1,4,5,6
	Reading: Science and Technology	1,4,9,10		
NGSS	Matter and Energy in Organisms and Ecosystems	LS2.A, LS2.B, LS2.C		
	Interdependent Relationships in Ecosystems	LS2.A, LS2.C, LS4.D		
	Growth, Development, and Reproduction of Organisms	LS1.B		
	Natural Selection and Adaptations	LS4.C		
EEEGL	Strand 1	C,E,G		
	Strand 2.2	A,C		

Teacher background: Different kinds of plants and animals have different needs. Some plants grow well only in sunny openings, for example, while some grow well in shade and others require special soil conditions or large amounts of water. Different species that live in the Sierra Nevada have different ways to survive fire and thrive afterward. These traits ("adaptations") are sometimes specific to a certain kind of fire, so changes in the kinds of fire or the frequency of fire may make life difficult for the organism.

In this activity, students teach each other about some of the species that live in California lower and upper montane forests and shrublands. Each student "adopts" a plant, animal, or fungus, prepares a mask or costume, and presents his or her organism to the class. Students use the two-page essays in the *FireWorks Encyclopedia.* They can seek information from other sources if you want them to do additional research, but that is not essential. Each student presentation should address the kind(s) of forest where the organism resides and the kind(s) of fire that the organism "likes" or "dislikes." The students will need that information when they work together to create a drama that illustrates a forest ecosystem's relationship with fire (**Activity M19 - Drama in the Forest: Fire and Succession, a Class Production**).

Additional information, written for professional land managers, is available for most of the species included in this activity – and hundreds of others throughout the United States - at https://feis-crs.org/feis/.

Materials and Preparation:

- Make a copy of **Table M11-1. Assignments and answer key for species in the FireWorks Encyclopedia.** You will use it to select the species to be presented, keep track of which species is assigned to which student, and evaluate student presentations and the written assessment.

- Decide if you want to cover both lower and upper montane forests; if you have a small class or limited time for Activity M19 (**Drama in the Forest: Fire and Succession, a Class Production),** you may want to choose just one, using the second column in **Table M11-1**.
- Decide how to assign species to students. You can let them choose or decide yourself ahead of time. Record species assignments in **Table M11-1.**
- Provide access for students to the **FireWorks Encyclopedia_Older grades.pdf** – either electronically, by printing the pages needed, or by loaning to students the pages from the printed version (in the trunk).
- Provide art supplies for masks or costumes, if needed.

Procedure:

1. Ask: When we say someone is a part of a *community,* what does that mean to you? What are some examples? There is great variety in human communities. Examples might include a family, class, school, town or city, sports team, club, or church. **Try to draw out these ideas:** A human community includes people and may also other living things, such as pets, livestock, and even fungi and germs! A *community* is a group of living things that have something in common.
2. Explain: An ecological community is also group of living things – that is, *organisms* - that have something in common. They usually live in the same kind of habitat and interact with one another through their needs for energy and other resources. Can you think of some organisms that live in the wildland communities of our mountains, the Sierra Nevada? Lots of answers are possible, including insects… fish… decomposers… and humans!
3. Explain: We are going to learn about some members of Sierra Nevada wildland communities and their relationships with fire. We'll only learn about a few of them though. There's a lot of *biodiversity* in our wildlands. Do you have any idea how many species occur in all of California? How could you find out? There are over 6,500 species of plants[1], 200 species of mammals[2], and 650 species of birds[3]. And that doesn't even include insects, fungi, or micro-organisms!
4. Explain: We will learn about some of the species that occur in *montane* communities (that is, in the mountains) at low elevations (*lower montane*, just above the foothills) or higher elevations (*upper montane*, higher and colder than lower montane, but still able to grow big, tall trees) or in large patches of shrubs (*chaparral*).

[1] California Department of Fish and Wildlife. 2017. Native plants. Available: https://www.wildlife.ca.gov/Conservation/Plants
[2] California Department of Fish and Wildlife. 2016. Complete List of Amphibian, Reptile, Bird and Mammal Species in California. Available: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=87155&inline
[3] California Bird Records Committee. 2017. Official California checklist. Available: http://www.californiabirds.org/checklist.asp

5. Explain the assignment and make Encyclopedia materials available: Each student will “adopt” an organism that lives in forests or shrublands of the Sierra Nevada. He or she will:

    - Learn about the organism from the essay in the Middle School-level *FireWorks Encyclopedia.*
    - Prepare a mask, costume, or puppet to use in a short presentation to teach the class about the organism (alternative ways to present the information include preparing a poster, computer presentation, or written abstract for an adult audience).
    - Give a 3- to 5-minute presentation on the organism that includes a basic description of the organism and its needs, what its habitat is like, the kind(s) of fire that occur there, and how it deals with fire.

Assessment:

1. Have each student present his/her 3-5 minute presentation (or other media product) to the class. Have the class take notes on each presentation, especially regarding fire.
2. Have each student give you 3 copies of his/her organism’s name, written on a small piece of paper. Put them in a bowl or hat.
3. After all students have presented, have each student pick 3 organism names from the hat (if they pick their own, they must pick again) and provide in writing for each one:
    - the kind(s) of communities where it lives –its favorite habitat
    - the kind(s) of fire preferred by the organism
    - the organism’s way(s) to deal with fire
    - ways in which the organism interacts with the other 2 organisms selected – or an explanation that it probably does NOT interact with them.

Evaluation:	Excellent	Good	Fair	Needs Improvement
Presentation	-Presentation was 3-5 minutes in length. -Student prepared a visual component. -Student provided and accurate description of organism and its needs, the kind(s) of communities where it lives, the kind(s) of fire that it prefers, and how it deals with fire. -A great deal of effort was put into visual aid and presentation.	-Presentation was slightly under or over 3-5 min. -Student prepared visual component. -Student provided a basic description of organism and its needs, the kinds of communities where it lives, the kind(s) of fire that it prefers, and how it deals with fire.	-Presentation was slightly or under or over 3-5 minutes. -Student prepared visual component. -Student's basic descriptions of organism, community type, and fires were inaccurate or missing important information.	-Presentation was greatly over or under 3-5 minutes. -Student did not prepare visual or put minimal effort into preparing it. -Basic information was largely inaccurate or incorrect.
Writing Component	-Student provided clear, detailed description of each organism's habitat, the type of fire that it prefers, its relationships with fire, and how it interacts with other organisms.	-Student correctly provided 3 of these 4 requirements for each organism: habitat, the type of fire that it prefers, relationships with fire, and interactions with other organisms.	- Student correctly provided 2 of these 4 requirements for each organism: habitat, the type of fire that it prefers, relationships with fire, and interactions with other organisms.	-Student's descriptions of organisms' habitat, the type of fire that it prefers, relationships with fire, and interactions were largely inaccurate and missing important information.

Table M11-1. Assignments and answer key for species in the *FireWorks Encyclopedia.*

Species Name	Student name	Sierra Nevada montane communities where species is most common*	Notes on habitat	Does not need fire, but some fire OK	Surface Fire OR small or patchy fires	Crown Fire/Fires that kill a lot of trees/shrubs	Almost any kind of fire	Little known about relation-ship with fire	Traits (if any) that help survive fire or thrive after fire
American black bear (Ursus americanus)		Lower and upper montane forest, chaparral	Uses most kinds of habitat.				x		Travels fast. Has large home range.
Annosum root rot (Heterobasidion annosum)		Lower and upper montane forest	Conifer forests					x	Persists in underground tree parts, living or dead.
Baker cypress (Hesperocyparis bakeri)		Lower and upper montane forest	Upper montane, sunny places			x			Serotinous cones.
Bark beetles (multiple species)		Lower and upper montane forest. Different species prefer different conifers.	Dense conifer forests				x		Prolific offspring. Able to fly to new forest or fire-weakened trees.

Species Name	Student name	Sierra Nevada montane communities where species is most common*	Notes on habitat	Does not need fire, but some fire OK	Surface Fire OR small or patchy fires	Crown Fire/Fires that kill a lot of trees/shrubs	Almost any kind of fire	Little known about relation-ship with fire	Traits (if any) that help survive fire or thrive after fire
Black fire beetle (Melanophila acuminata)		Lower and upper montane forest	Burning or recently-burned forest			x			Heat sensors on thorax, smoke-sensitive antennae.
Black-backed woodpecker (Picoides arcticus)		Lower and upper montane forest	Recently burned forest, rotten trees			x			Black back is camouflage on burned trees. Can fly to escape fire.
Bracken fern (Pteridium aquilinum)		Lower and upper montane forest	All kinds of habitat, especially sunny				x		Deep, thick rhizomes. Rapid growth in sunny places.
California black oak (Quercus kelloggii)		Lower montane forest, chaparral	Foothills & lower montane		x				Thick bark on mature trees. Ability to sprout after top-kill.
California red fir (Abies magnifica var. magnifica)		Upper montane forest	Upper montane forest	x	x				Thick bark on old trees.

Species Name	Student name	Sierra Nevada montane communities where species is most common*	Notes on habitat	Does not need fire, but some fire OK	Surface Fire OR small or patchy fires	Crown Fire/Fires that kill a lot of trees/shrubs	Almost any kind of fire	Little known about relation-ship with fire	Traits (if any) that help survive fire or thrive after fire
California spotted owl (Strix occidentalis occidentalis)		Lower and upper montane forest	Old-growth trees, patchy variety in habitat	x	x				Easy to fly away from fire, but nest trees may be killed by severe fires.
Canyon live oak (Quercus chrysolepis)		Lower montane forest, chaparral	Foothills, lower montane, chaparral		x	x			Sprouts well from root crown.
Cheatgrass (Bromus tectorum)		Lower montane forest mostly, chaparral	Sunny places with bare soil				x		Prolific seed producer. Seeds usually on ground before fire season.
Deer brush (Ceanothus integerrimus)		Lower and upper montane forest, chaparral	All habitats, especially upper montane chaparral			x	x		Has some sprouting ability. Seeds stored in the soil. Fire helps them germinate.

Species Name	Student name	Sierra Nevada montane communities where species is most common*	Notes on habitat	Does not need fire, but some fire OK	Surface Fire OR small or patchy fires	Crown Fire/Fires that kill a lot of trees/shrubs	Almost any kind of fire	Little known about relation-ship with fire	Traits (if any) that help survive fire or thrive after fire
Deer mouse (Peromyscus maniculatus)		Lower and upper montane forest, chaparral	All kinds of habitat				x		Burrows underground. Lots of food soon after fire.
Douglas-fir (Pseudotsuga menziesii var. menziesii)		Lower montane forest	Foothills, montane forest.	x	x				Thick bark on old trees. Prolific reproduction.
Dusky-footed woodrat (Neotoma fuscipes)		Lower montane forest, chaparral	Foothills, oak woodlands		x				Can run from fire. Fire improves habitat, but not right afterward.
Fisher (Pekania pennanti)		Lower and upper montane forest	Forests, especially large & complex ones.	x					Can run from fire. Doesn't use burned areas much – especially large burned areas.
Fox sparrow (Passerella iliaca)		Chaparral	Chaparral				x		Can fly from fire. Fire improves habitat, but not right away.

Species Name	Student name	Sierra Nevada montane communities where species is most common*	Notes on habitat	Does not need fire, but some fire OK	Surface Fire OR small or patchy fires	Crown Fire/Fires that kill a lot of trees/shrubs	Almost any kind of fire	Little known about relation-ship with fire	Traits (if any) that help survive fire or thrive after fire
Incense-cedar (Calocedrus decurrens)		Lower montane forest	All kinds of forest		x				Thick bark on old trees
Jeffrey pine (Pinus jeffreyi)		Upper montane forest mostly	Lower & upper montane forest		x				Has thick bark, even as sapling. Loses low branches easily.
Mariposa lily (Calochortus spp.)		Lower and upper montane forest, chaparral	Montane forest, especially in openings & dry soil				x		Sprouts from deep bulb
Mountain lion (Puma concolor)		Lower and upper montane forest, chaparral	All kinds of habitat				x		Runs from fire. Likes to hunt edges of burns, where deer are plentiful.
Mountain whitethorn (Ceanothus cordulatus)		Lower and upper montane forest, chaparral	Chaparral, woodland, forest				x		Sprouts from lignotubers. Fire helps seeds open.

Species Name	Student name	Sierra Nevada montane communities where species is most common*	Notes on habitat	Does not need fire, but some fire OK	Surface Fire OR small or patchy fires	Crown Fire/Fires that kill a lot of trees/shrubs	Almost any kind of fire	Little known about relation-ship with fire	Traits (if any) that help survive fire or thrive after fire
Mountain yellow-legged frog (Rana sierrae and R. muscosa)		Upper montane forest	Deep mountain lakes, slow-moving streams	x				?	Likely to survive because of wet or water habitat. Habitat may get too warm after fire.
Mule deer (Odocoileus hemionus)		Lower and upper montane forest, chaparral	All kinds of habitat. Variety is best.		x				Runs from fire. Browses in burned areas (though not right away) but stays close to cover.
Northern goshawk (Accipiter gentilis)		Lower and upper montane forest	Forests with some big trees for nests		x				Flies from fire. Likes variety in habitat, including burned areas.
Ponderosa pine (Pinus ponderosa var. benthamiana, P. p. var. ponderosa)		Lower montane forest	Foothills & lower montane forest		x				Has thick bark, even as sapling. Loses low branches easily.

Species Name	Student name	Sierra Nevada montane communities where species is most common*	Notes on habitat	Does not need fire, but some fire OK	Surface Fire OR small or patchy fires	Crown Fire/Fires that kill a lot of trees/shrubs	Almost any kind of fire	Little known about relation-ship with fire	Traits (if any) that help survive fire or thrive after fire
Quaking aspen (Populus tremuloides)		Lower and upper montane forest	Forests & woodlands, especially moist sites				x		Sprouts prolifically from roots. May reproduce from seed in burned places.
Ross's sedge (Carex rossii)		Lower and upper montane forest	Montane forests & meadows. Needs sunlight.				x		Sprouts from rhizomes, grows well from seed in sunny openings.
Sierra gooseberry (Ribes roezlii)		Lower montane forest, chaparral	Chaparral, woodlands, open forests			x			Sprouts from root crown. Fire helps open seed, provides sunny openings to grow.
Sierra lodgepole pine (Pinus contorta var. murrayana)		Upper montane forest	Upper montane forest				x		Does not usually survive fire, but seedlings grow very well after fire.

Species Name	Student name	Sierra Nevada montane communities where species is most common*	Notes on habitat	Does not need fire, but some fire OK	Surface Fire OR small or patchy fires	Crown Fire/Fires that kill a lot of trees/shrubs	Almost any kind of fire	Little known about relation-ship with fire	Traits (if any) that help survive fire or thrive after fire
Sticky whiteleaf manzanita (Arctostaphylos viscida)		Lower montane forest, chaparral	Chaparral, woodlands, & sunny spots in forests			x			Very flammable. Killed by fire, but fire is needed to open seeds.
Sugar pine (Pinus lambertiana)		Lower montane forest	Montane forests		x				Thick bark on old trees & high, open crown help survive surface fires.
Wavyleaf soap plant (Chlorogalum pomeridianum)		Lower montane forest, chaparral	Grassland, chaparral, woodland, forests with openings				x		Big, deeply buried bulb. Flowers prolifically after fire.

Species Name	Student name	Sierra Nevada montane communities where species is most common*	Notes on habitat	Does not need fire, but some fire OK	Surface Fire OR small or patchy fires	Crown Fire/Fires that kill a lot of trees/shrubs	Almost any kind of fire	Little known about relation-ship with fire	Traits (if any) that help survive fire or thrive after fire
Webber's milkvetch (Astragalus webberi)		Lower montane forest, chaparral	Chaparral, lower montane – especially in disturbed soil					x	Not certain about sprouting ability. Seedlings may grow better in burned than unburned places.
Western gray squirrel (Sciurus griseus)		Lower montane forest	Oak woodlands, oak-pine forests		x				Runs from fire. Uses burned areas where oaks survived. Caches seeds in burned places.
Western wood-pewee (Contopus sordidulus)		Lower montane forest	Forests & woodlands with openings		x				Flies from fire, but nest & perches may burn. Uses patchy habitat, not big burns.

Species Name	Student name	Sierra Nevada montane communities where species is most common*	Notes on habitat	Does not need fire, but some fire OK	Surface Fire OR small or patchy fires	Crown Fire/Fires that kill a lot of trees/shrubs	Almost any kind of fire	Little known about relation-ship with fire	Traits (if any) that help survive fire or thrive after fire
White fir (Abies concolor)		Lower montane forest mostly	Montane forests, especially if dense & shady	x					Old trees have thick bark.
White pine blister rust (Cronartium ribicola)		Lower and upper montane forest, but in the Sierra, it is most common in sugar pine-lower montane	5-needled pines & gooseberry bushes (& a few other species)				x		Cannot survive fire but spreads easily from spores on live host plants near burned areas.
Yellow star thistle (Centaurea solstitialis)		Lower montane forest, chaparral	Grasslands & areas with disturbed soils				x		Reproduces from seeds in soil or brought in from other areas.

*Many species occur in other communities in addition to lower and upper montane forests and shrublands (chaparral). Several species are common in low- elevation foothill communities (e.g., canyon live oak, cheatgrass), and other species are common in high-elevation subalpine communities (e.g., Sierra lodgepole pine, mountain yellow-legged frogs).

12. Tree Parts and Fire: "Working Trees" Jeopardy-style Game

Lesson Overview: In this activity, students learn to name the parts of a tree, describe their functions, and describe how some of these plant parts can help the tree survive fire, avoid severe fire, or reproduce after fire.

Lesson Goal: Increase students' understanding of how trees function and how they may be affected by different kinds of wildland fires.

Subjects: Science, Reading, Speaking and Listening

Duration: Two half-hour sessions and homework to complete prior to activity

Group size: Whole class, working in teams (10 teams maximum)

Setting: Classroom

New FireWorks vocabulary: *see terms in Handout M12-1.*

Objectives: Given a list of tree parts and other terms, students can

- Describe a tree part, a part of the tree's environment, and/or a type of fire to the class.
- Apply the correct term to a definition of a tree part or adaptation to fire in a Jeopardy-style game.
- Describe how specific tree parts and characteristics enable some trees to avoid, survive, or thrive after surface fire, crown fire, and ground fire.

Standards:		6th	7th	8th
CCSS	Reading: Informational Texts	4,10	4,10	4,10
	Speaking and Listening	1,4,6	1,4,6	1,4,6
	Language	1,2,3,4	1,2,3,4	1,2,3,4
	Reading: Science and Technology	4,7,8,9,10		
NGSS	Matter and Energy in Organisms and Ecosystems	LS2.A, LS2.B,LS2.C		
	Natural Selection and Adaptation	LS4.C		
	Growth, Development, Reproduction of Organisms	LS1.B		
EEEGL	Strand 2	B,C		

Teacher Background: To understand how fire affects organisms in the ecosystem and shapes plant communities, students need to know a few terms and be able to identify some tree species. This activity challenges them to master 23 terms, many of which (such as leaf and branch) they already know. The activity consists of two parts. In Part I, students teach their classmates some terms about tree morphology, the forest environment (litter, duff, and mineral soil), and types of fire (surface, crown, and ground fire). The second part is a Jeopardy-style game containing 25 definitions plus a bonus question (***M12_Jeopardy_FireWorks1.pptx***).

Use the directions on Slide 1 and work with the game (Slide 2) ahead of time to become familiar with the process of moving/deleting boxes and scoring students' answers.

Different characteristics enable trees (and other plants) to avoid specific kinds of fire, survive fire, or reproduce and thrive after fire. For example:

- Thick bark can protect a tree's sensitive phloem and cambium from the heat of surface fires. However, it provides no protection from crown fires.
- If a tree tends to shed its low branches, fires are less likely to climb from the forest floor into the tree crowns than if the tree's branches are continuous from ground to crown.
- If young trees of a species can grow really fast, getting their leaves and branches high above the ground, they may be able to survive surface fires even when young.
- Roots that grow deep in mineral soil are protected from the heat of surface and ground fires. However, deep roots don't prevent damage to the cambium from surface fires or damage to the leaves and buds from crown fires.
- If a tree can protect its seeds from fire, new trees can become established afterwards. Tightly sealed cones protect the seeds of some trees from crown fire. Burial protects seeds from all kinds of fire – unless they are in duff or organic soil, which can burn if it dries out.
- If a tree can sprout from the roots after its top is killed, it can survive surface and crown fire; its ability to survive ground fire depends on soil properties and how deeply its roots are buried.

Materials and preparation:

- Download the Jeopardy game (***M12_Jeopardy_FireWorks1.pptx***) and **make a backup copy too**. BE SURE TO READ THE DIRECTIONS on Slide 1 and practice working with the game on Slides 2-3. The answers are on Slides 4-5 and also printed below. The remaining slides are for backup, so you can restore a layer if you need to. Remember to minimize the left margin when you display the presentation, so students can't read the key!

- Download ***M12_WorkingTreeDiagram_Blank.pptx*** so you can project it on the board during student presentations. Each presenter will sketch where each term occurs on the board. OPTION: Create a sketch like this one, where students can add and label their tree parts/terms.

- Print 1 copy/student: **Handout M12-1: Tree Parts and Kinds of Fire**

  Handout M12-2: Working Trees.

- At least 1 day before doing this activity, give each student a copy of **Handout M12-1: Tree Parts and Kinds of Fire**. Explain that they will play a Jeopardy-style game and compete for points based on their understanding of these terms and what the definitions say about how trees "deal with" fire – that is, how they avoid certain kinds of fire, survive fire, or reproduce or regrow after fire. Decide – and tell them – whether or not they will be allowed to use the sheet during the game.

- Obtain prize(s) for the winning team, if you intend to award anything.

Procedure - Part I*:

1. Explain: Look up 1-2 term(s), as assigned, using **Handout M12-1: Tree Parts and Kinds of Fire** and at least 1 other source. Develop a 1-2 minute presentation to teach the class about the term(s). Your presentation must include a visual or digital component such as a sample, photograph, podcast, video (no longer than 60 seconds), or PowerPoint.
2. Assign each student 1-2 terms from **Handout M12-1.** There are 23 terms total.
3. Have students teach their terms to the class. Have each student sketch and label his/her terms on the board projection/sketch. Have the class copy this information and make notes about fire-related information.

   NOTE: It is best to have <u>branches</u> presented before leaves, buds, cones, and catkins; <u>cones and catkins</u> presented before seeds; and <u>roots</u> presented before sprouts.

4. Have students take their notes and handouts home to study for the Jeopardy game.

*If you only have one class period available, skip Part I and have students review **Handout M12-1** as homework before Part II.

Procedure - Part II:

5. Explain: You will compete in a Jeopardy-style game to show your understanding of the information on the handout. Before beginning, are there any questions about the handout, any terms or concepts that you don't understand? Answer questions…
6. Set up teams.
7. Explain:
   - Explain the procedure. (**See the directions on Slide 1 of the game.)**
   - Tell students whether they are or are not allowed to use the handout during the game.
   - Play the game (***M12_Jeopardy_FireWorks1.pptx***). See the **FireWorks Jeopardy: answer key** below.
   - Present award to the winning team?

Assessment: Give each student a copy of **Handout M12-2: Tree Parts and Kinds of Fire**. Go through directions as needed. Have students complete the handout.

Evaluation:

	Full Credit	Partial Credit	Less than Partial Credit
Presentation	-Student presented accurate information in a clear and concise way. -The visual/digital component was relevant and helpful	-Student presented information that contained some misinformation (*which the teacher corrected*). -The visual/digital component was present but only slightly relevant.	-Student presented mostly misinformation -Visual/digital component was distracting or missing
Jeopardy Game	-Student participated consistently in jeopardy game by contributing to group discussions to determine answer, presenting answer for the group, listening, and giving other group members a chance to speak.	-Student participated sporadically in game by listening, occasionally contributing to group discussion, and presenting the group's answer at least once.	-Student did not participate in jeopardy game by listening to or engaging in group discussion or presenting group's answer.
Written component (Handout M12-2)	-Student correctly labeled 8-10 parts on diagram. -Student correctly described 3 adaptations that can help the tree survive or grow after ground, surface, and crown fire.	-Student correctly labeled 5-8 parts on diagram. -Student correctly described 1-2 adaptations that can help the tree survive or grow after different types of fire.	-Student correctly labeled less than 5 parts on diagram. -Student did not describe any adaptations that can help the tree survive or grow after fire.

FireWorks Jeopardy: answer key

	Growth	Transport	Support	Protection & Habitat	Helps deal with what kind of fire?
$10	Makes food **Leaf**	Absorbs water from soil **Root**	Treetop **Crown**	Tree skin **Bark**	Resin-sealed cones **Crown fire**
$20	Holds baby tree **Seed**	Pumps water up from roots **Xylem or sapwood**	Connects leaves to trunk **Branch**	Holds conifer seeds **Cone**	Thick bark **Surface fire**
$30	Makes new xylem & phloem **Cambium**	Helps conifer seed float from tree **Seed wing**	Supports crown, connects roots to crown **Trunk**	Fallen leaves **Litter**	Deep roots in mineral soil **Ground fire**
$40	Holds next year's leaves **Bud**	Delivers nutrients from leaves **Phloem**	Inner wood **Heartwood**	Dead tree with broken top **Snag**	Seedlings grow fast **Surface fire**
$50	Can regrow its top if killed **Sprouter**	Helps seeds fly miles on wind **Catkin**	Anchors trunk in soil **Root**	Layers of rotting leaves **Duff**	Low branches drop off **Crown fire**

FireWorks Final Question: answer key

Wager your winnings:

Deep duff can protect a tree from fire or make it more vulnerable. How?

Deep duff can protect a tree's cambium and roots until it dries out. After the duff dries, it burns slowly but hot. That kills the tree's shallow roots and the cambium around the tree's base.

Handout M12-1: Tree Parts and Kinds of Fire

Study this page to prepare for the "Working Trees" Jeopardy-style game.

Bark: the outside covering on a tree's trunk and branches, the tree's "skin." Thick bark can protect the tree from surface fire.

Branch: limb of a tree or shrub that grows out from the trunk and holds leaves up in the light. Some trees drop their low branches as they age, which helps keep surface fires on the forest floor, so the tree can avoid crown fire.

Bud: The cells that will grow next year's leaves and branches. Located at the tree's top and the tips of branches. Similar cells occur at the tips of roots.

Cambium: the layer of living cells under a tree's bark that produces the xylem and phloem layers

Catkin: lightweight, fluffy package of seeds. The "fluff" helps the seeds float a long way on the wind sometimes many miles.

Cone: the package in which a conifer stores its seeds. If cones are sealed tight with resin, the seeds inside may survive crown fire and be released soon afterward.

Crown: a tree's top, which holds most of its leaves and buds

Crown fire: fire that spreads through the crowns of trees and shrubs. Crown fires are usually ignited from surface fires. They are common in conifer forests and chaparral-type shrublands.

Duff: the layer of soil that is made up of dead, rotting plant parts. Duff is below litter and above mineral soil.

Ground fire: fire that burns in the duff and other organic material in the soil. Ground fires usually burn slowly, with lots of smoldering instead of long flames. They produce lots of heat.

Heartwood: inner wood of a tree, which helps it stand strong and resist decay

Leaf: the green part of a plant that uses sunlight, water, and carbon dioxide to make "food"

Litter: the layer of dead leaves and other plant matter, not yet decayed, at the top of the forest floor

Mineral soil: soil that has no plant or animal parts so it cannot burn

Phloem: the layer of living cells under a tree's bark that moves nutrients from one place to another, especially from leaves to other parts of the tree

Root: the part of a plant that lives underground, collects water and minerals from the soil, and keeps it firmly planted in the soil. If the roots are buried deep in mineral soil, they may be able to survive a ground fire.

Seed: a very tiny, living plant—just waiting to grow—plus a package of nutrients and a protective covering. If seeds are sealed tight inside a cone, they may survive crown fire. If they're embedded in moist duff, they may survive surface fire. If they're buried in mineral soil, they may survive ground fire.

Seed wing: part of a conifer seed that helps it float away from the parent tree when it falls

Snag: a dead tree, often with a broken top

Sprouter: a kind of plant that can grow from underground parts if its top is killed off

Surface fire: a fire that burns the litter, grasses, shrubs, and wildflowers on the forest floor but does not burn the crowns of trees or the duff layer.

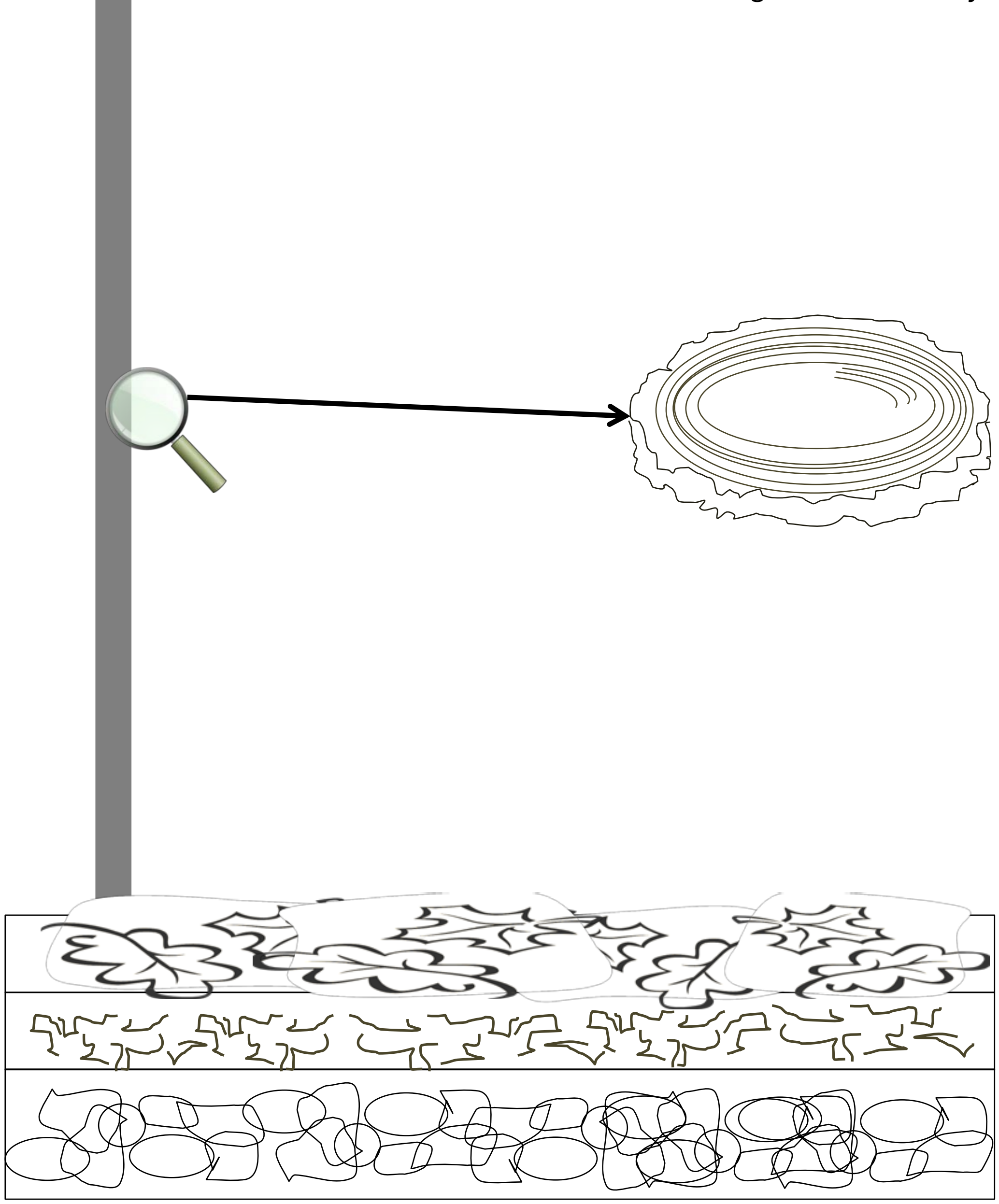
Trunk: the stem of a tree. The faster the trunk grows, the sooner its crown will be out of reach from surface fires.

Xylem: the layer of hollow wood cells inside the cambium that pump water from roots to leaves. Also called sapwood.

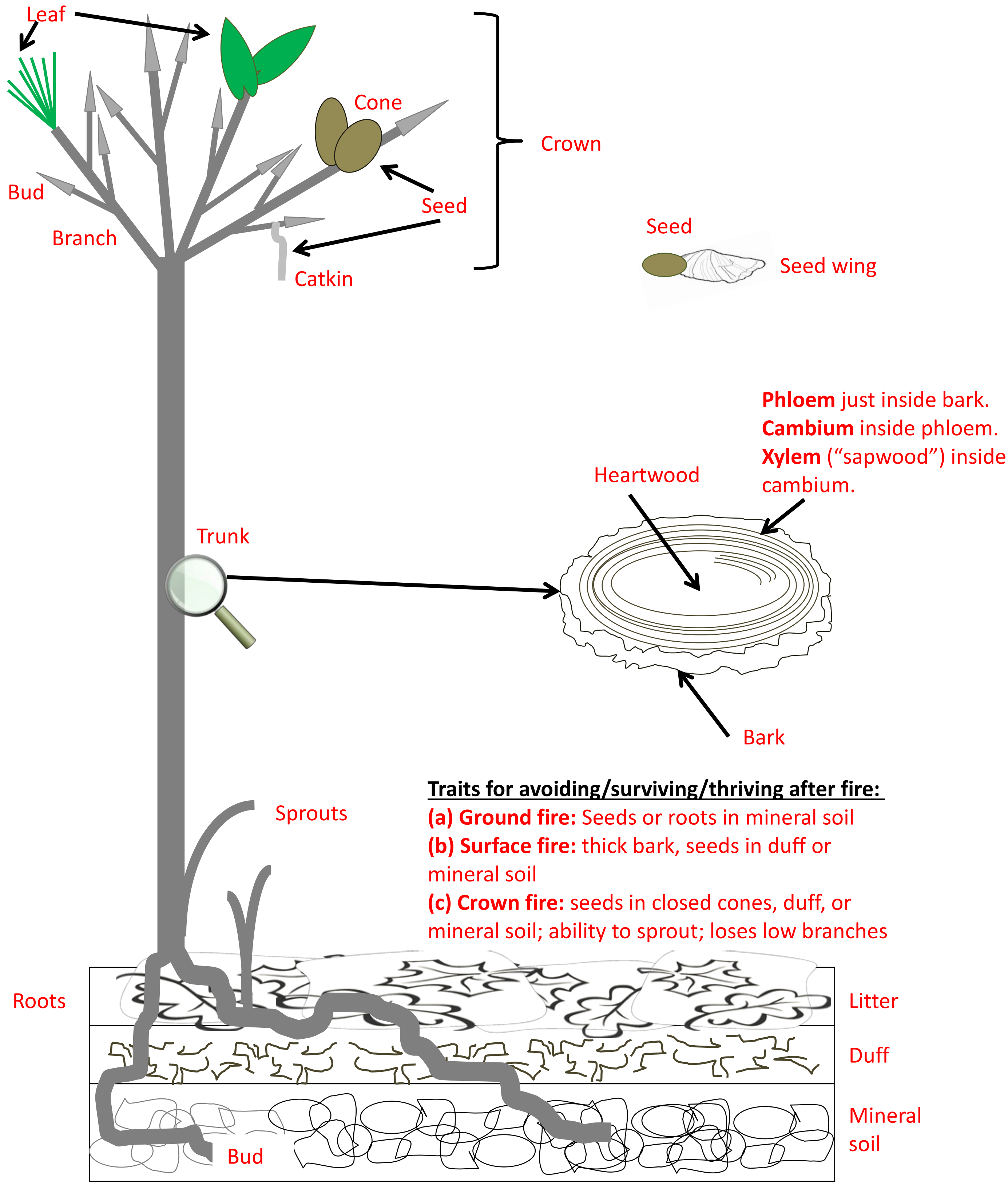
Handout M12-2: Working Trees

Name ______________

1. Sketch ten parts of this tree and/or its environment. Use terms from Handout M12-1. Label each part.
2. Name (a) one feature that can help the tree survive *ground fire*, (b) one that can help it survive *surface fire*, and (c) one that can help it avoid or survive or grow after *crown fire*.



Teacher's Answer Key for Handout M12-2: Working Trees



<u>**Traits for avoiding/surviving/thriving after fire:**</u>

(a) Ground fire: Seeds or roots in mineral soil

(b) Surface fire: thick bark, seeds in duff or mineral soil

(c) Crown fire: seeds in closed cones, duff, or mineral soil; ability to sprout; loses low branches

13. Tree Identification: Figure out the "Mystery Trees"

Lesson Overview: In this activity, students observe and record information on botanical specimens, then use each other's observations to identify 12 tree species that live in Sierra Nevada montane forests.

Lesson Goals: Increase students' understanding that trees have characteristics unique to each species and these can be used to identify them.

Subjects: Science, Mathematics, Writing, Reading, Speaking and Listening

Duration: Two half-hour sessions

Group size: Whole class, working in 12 teams

Setting: Classroom

New FireWorks vocabulary: *bundle, scale*

Objectives: Given descriptions of individual tree species written by their peers, students can examine a sets of photos and botanical specimens to identify a tree species.

Standards:		6th	7th	8th
Common Core ELA	Reading: Informational Texts	4,7,10	4,10	4,10
	Speaking and Listening	1,6	1,6	1,6
	Language	1,2,3,4,6	1,2,3,4,6	1,2,3,4,6
	Reading: Science and Technology	3,4,7,9,10		
NGSS	Matter and Energy in Organisms and Ecosystems	LS2.A,		
	Growth, Development, Reproduction of Organisms	LS1.B		
	Natural Selection and Adaptation	LS4.C		
EEEGL	Strand 1	A,B,C,E,F,G		

Teacher Background: A wildland ecosystem is characterized by diversity. The diversity of tree species is an important characteristic of forests and contributes to the kinds of fire that occur there. To understand the complexity of fire's role in forests, students must be able to distinguish among tree species. In this activity, they use their observation skills to describe and identify 12 important trees in the Sierra Nevada. They work in 12 teams, since there are 12 species represented in the "Mystery Trees" materials.

This activity has two steps. In the first, students describe a “known” species and record their observations on a handout. In the second, which is also the Assessment, they use each other’s observations to identify ALL of the species.

If you can visit a forest with the class, they can use the same set of handouts to identify trees in the field. (However, note that a winter visit could prove frustrating if deciduous trees have already shed their leaves.)

If you’d prefer to do a tree identification activity in one class period that uses a dichotomous key, use elementary activity: E10_MysteryTrees.

Materials and preparation:

- Print a copy of **Handout M13-1: Description of a Tree Species** for each team (12 copies if identifying all 12 trees).
- If possible, provide some field guides for students to examine at the end of the activity. A good resource is *Pacific Coast Tree Finder: A Pocket Manual for Identifying Pacific Coast Trees* by Tom Watts.
- Assemble 12 stations in the classroom, each containing a box or grocery bag with the following items for a single species:

  Tree Bark/trunk specimen
  Cone or flower specimen
  Foliage specimen
  Set of photos of the species (available: ***M13_TreePhotoPacket.pdf,*** print double sided)
  Species name label (available: ***M13_Labels.pdf,*** laminate & cut each species into own label)
  Ruler

- See below: “DURING A BREAK OR BEFORE THE NEXT CLASS” for preparation instructions for Step 2 of the activity.

Procedure: STEP 1 – FIRST CLASS SESSION – “KNOWN SPECIES”

1. Ask: Can you name any tree species that live in the Sierra Nevada? When you see a tree in the woods or on a mountainside, how do you know what kind it is – that is, how can you identify it? Open-ended discussion. You could note species names a 1-2 characteristics on the board.
2. Explain: This activity will add to your skill in identifying trees. Each team will describe a tree species using the specimens and photos at one station. Then in the next class, we’ll use your descriptions to identify ALL of the specimens we have here – 12 species in all. YOU HAVE TO DO A GOOD JOB WITH YOUR DESCRIPTION TODAY SO EVERYONE ELSE CAN USE IT CORRECTLY TO IDENTIFY THE “MYSTERY TREES” TOMORROW! By the time you’ve honed

your observation skills and used them to identify tree species here in class, you'll be able to identify the same species in the woods.

3. Assign a team of students to each station. Instruct them to record the species name at that station on **Handout M13-1: Description of a Tree Species** and then fill out the handout with their observations on that species. They should NOT put the species' code letter on the handout! When they have completed the handout, they should let you know and you'll check their work. Remind them that neatness counts because they will use other teams' handouts in the next class period.
4. As each team completes the handout, visit their station. Remove the species name label. Make sure the code letter is NOT on the handout. Check the handout for completeness and accuracy. Ask the team to revise it, if necessary, so it will be useful for other students in identifying mystery trees.
5. After you approve the team's handout, collect it for copying. If you are not going to do Step 2 right away, have them place their specimens back in the box or bag.

DURING A BREAK OR BEFORE THE NEXT CLASS:

Make a set of booklets containing all 12 handouts so you can give a copy to each student or team, depending on how you want to do Step 2. A cover page for the booklet is provided at the end of this activity (***Mystery Tree Booklet, Sierra Nevada Montane Forests*** *and as a separate file:* ***MysteryTreesBookletCover***).

Assessment: STEP 2 – NEXT CLASS SESSION – "MYSTERY TREE SPECIES"

1. Set up the stations again – this time without species name labels.
2. Give a copy of the Mystery Trees Booklet (their completed handouts for all 12 species) to each student or team.
3. Explain: Each station contains a "mystery tree." You should recognize the one your team described, but the others may be "mysteries" for you. Circulate from station to station in any order. Use the observations in the handout booklet to identify each tree. **Then write the tree's one-letter code in the upper right corner of the correct handout page and circle it.**
4. After the activity is complete, explain that only 12 species are included in this activity, but there may be many more native trees in the forests of your area. Thus you can use this booklet to identify trees in the field, but you'll probably find some in the field that you can't identify. That's what local *field guides* are for. If possible, show them some field guides from a library or another collection.

Evaluation:

Code letters for the tree species:

Baker cypress	A
California black oak	C
California red fir	S
Canyon live oak	P
Douglas-fir	E
Incense-cedar	J
Jeffrey pine	K
Ponderosa pine	Q
Quaking aspen	B
Sierra lodgepole pine	M
Sugar pine	T
White fir	X

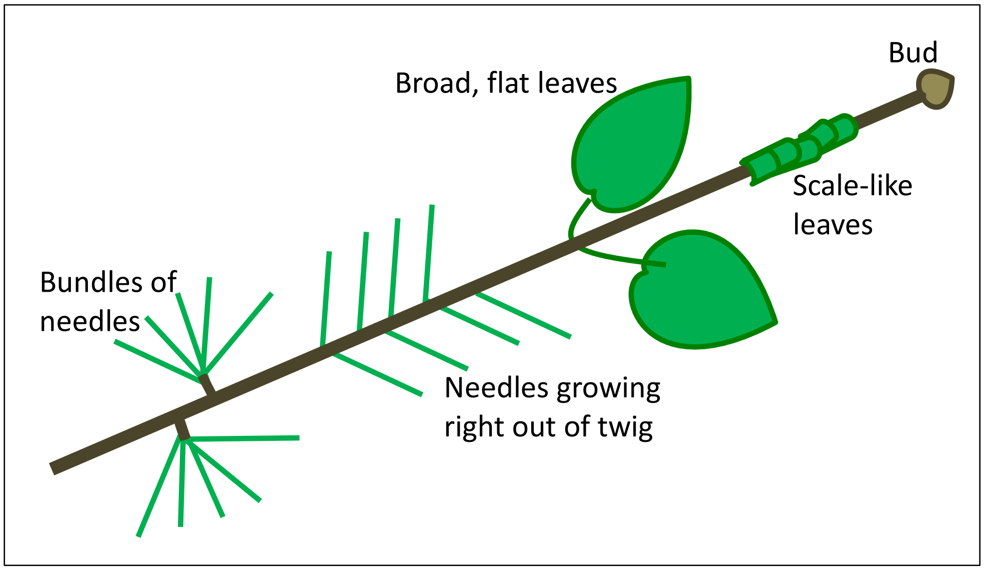
Full Credit	Partial Credit	Less than Partial Credit
-Student/team correctly identified 10-12 species	-Student/team correctly identified 7-9 species	-Student/team correctly identified fewer than 7 species

Handout M13-1: Description of a Tree Species

Team Members: ____

1. Are the leaves *broad and flat* (more than 1 centimeter wide)… or *narrow and needle-shaped…* or *a long series of overlapping scales*? _______________

2. How big are the leaves? ______ centimeter(s) long by ______ centimeter(s) wide



3. If the leaves are NOT scales, do they grow in bundles or individually right out of the twig?

   ____

4. Find the biggest bud. This is at the tip of the twigs. How big is it?

   ______ centimeter(s) long by ______ centimeter(s) wide

5. Do the buds have pointy tips or rounded tips? ____________________

6. Does the tree put its seeds in flowers or cones? ______________________

7. Describe the flowers, seeds, or cones — size, color, how they look:

8. How thick is the bark? _______________________ centimeter(s)
   Describe the bark:

9. Do the branches reach from all the way from the treetop to close to the ground (view the photos)? _________________

10. Describe two other characteristics that would help someone identify this tree:

Mystery Trees Booklet

Sierra Nevada Montane Forests

Name(s): ____

1. Use the descriptions in this booklet to identify the tree species at each station.
2. Write the correct code letter for each species in the upper right corner of each page (Handout M13-1: Description of a Tree Species)
3. Circle the code letter so it's easy to see.

14. Who Lives Here and Why? Modeling Forest Communities

Lesson overview: In this activity, students create a graphical model of forest communities in the northwestern Sierra Nevada. They create the model using a table that describes the current distribution of tree species on a fictitious mountainside called Sasquatch Peak. Students then use the model to describe the species composition of current forest communities and to predict the potential effects of changing climate conditions on the distribution of species.

Subjects: Science, Mathematics, Reading, Speaking and Listening
Duration: one half-hour class session, possibly followed by a station activity
Group size: Whole class
Setting: Classroom
FireWorks vocabulary: *aspect, climate, climate change, distribution (of a species), elevation, environmental conditions, gradient, migration/species migration*

Goals: To increase students' understanding that

- forest communities develop under specific environmental conditions
- species with similar needs are likely to occur together
- species distributions and community composition may change as climate conditions change
- models can be used to describe what we understand and predict what may happen in the future

Objectives:

- Students can list tree species that are likely to occur together in montane forests of the Sierra Nevada
- Students can use a graphical model to predict some changes that could occur as climate conditions change.

Standards:		6th	7th	8th
CCSS	Writing	4,10	4.1	4,10
	Reading: Informational Text	4,10	4,10	4,10
	Speaking and Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Reading: Science and Technology	3,4,7,10	3,4,7,10	3,4,7,10
	Writing: Science and Technology	2	2	2
NGSS	Interdependent Relationships in Ecosystems	LS2.A		
	Weather and Climate	ESS2.D, ESS3.D		
	Natural Selection and Adaptation	LS4.B, LS4.C		
	Growth, Development, Reproduction of Organisms	LS1.B, LS4.B		
EEEGL	Strand 1	A,C,E,F,G		

Teacher background:

Every species needs certain *environmental conditions* in order to survive and reproduce. Trees, for example, need a certain amount of sunlight and moisture and certain temperature conditions. They may also need a specific day length to begin growing and specific soils to provide nutrients and moisture. Environmental conditions are a very important aspect of a species' habitat.

In this activity, students use a simplified description of the environmental conditions required by 12 tree species to describe forest communities and how the species in these communities might respond to climate change. The species studied here occur in montane forests of the northwestern Sierra Nevada; students learned about their ecology in Activity 11 and how to identify them in Activity 13.

The description of environmental conditions in this activity is limited to species' moisture requirements and elevational ranges. These two characteristics are represented as *gradients* from "dry" to "very moist" and "hot" at low elevations to "cool" at high elevations on a fictitious mountain called Sasquatch Peak. These conditions are oversimplified, since a site can be hot or cool, dry or moist not only due to its elevation and location relative to ridges and creek beds but also due to its *aspect*, slope steepness, soil properties, and many other factors. The sketch of the mountainside, then, is a graphical model of the combinations of moisture and elevation available to trees. Students will use it to do what models do best: describe what we know and predict what could happen if conditions changed.

Handout M14-1: Where Can Trees Grow on Sasquatch Peak? describes the most common conditions in which each tree species occurs. (Note that these conditions are the MOST COMMON ones, not the OUTER LIMITS of what the species can tolerate.) Given the descriptions in the table, students can show where each species is likely to occur on the mountainside model. They can also predict which species are likely to occur together, thus forming a forest community. And they can predict how the best locations for a species might change if climate conditions change. If individual trees in the current locations can spread their seeds or otherwise reproduce in a "new" location for them – and then thrive and reproduce there - we say the species has *migrated* to the new location. If they cannot, the species may gradually die out.

This activity provides a very simplified model of what may happen to tree distributions as climate conditions change. The only variables considered here are temperature and moisture. In reality, tree distributions are much more complex, and predicted changes in distribution must address variables including seed dispersal, species interactions, insects and diseases, connectivity of habitat, and changes in fire frequency, severity, and size.

Here is some further background on climate change and species migration:

Assisted migration: https://earlycareerecologists.wordpress.com/2013/01/16/trees-on-the-move-debating-assisted-migration-in-climate-change-mitigation/

Global species migration: https://www.washingtonpost.com/national/health-science/up-and-up-plants-and-animals-migrating-as-climate-changes/2011/08/18/gIQAzlTxNJ_story.html

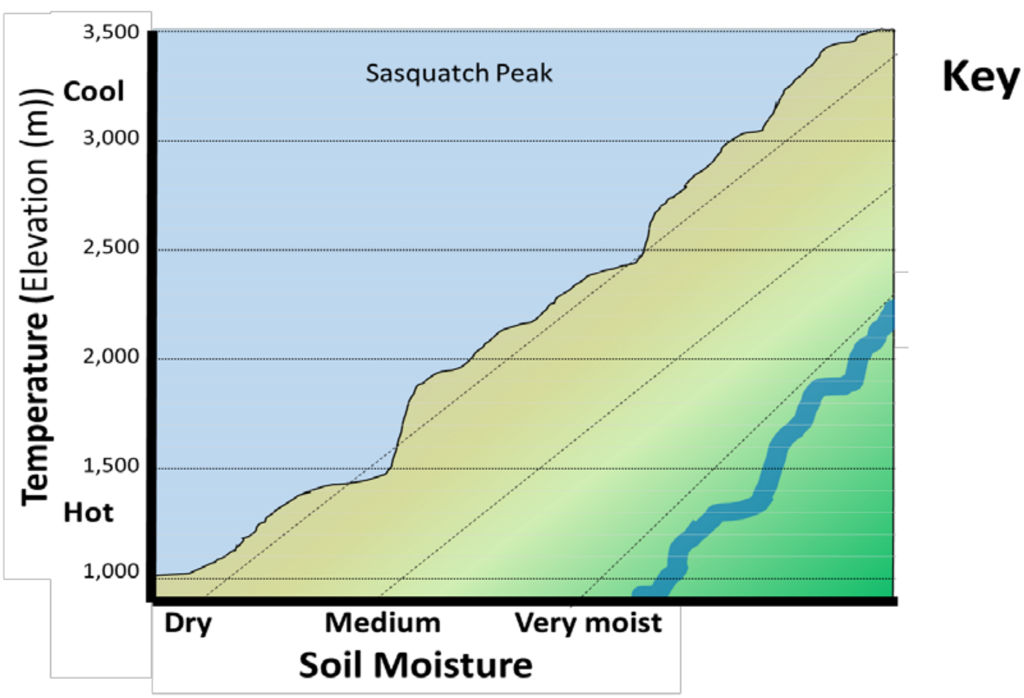
Tree migration, eastern U.S. examples:
http://news.nationalgeographic.com/news/2009/02/090209-trees-migrating-north.html

"How Global Warming is Changing the Wild Kingdom" (http://www.livescience.com/3864-global-warming-changing-wild-kingdom.html)

"Animals and Plants Adapting to Climate Change" (http://www.livescience.com/3863-animals-plants-adapting-climate-change.html)

Materials/Preparation:

- Make 1 copy/student:
  Handout M14-1: Where Can Trees Grow on Sasquatch Peak
  Handout M14-2: Trees in a Changing Environment
- Download the template for the Sasquatch Peak Forest Model (***GradientModelTreeDistributions.pptx***, Slide 1, shown below) so it can be projected on a whiteboard -- <u>or</u> -- project and copy it onto butcher paper. If you have a smartboard with memory, trace the axes and labels from the projection with black marker.
- Markers - 12 colors other than black



Procedure

1. Display the Sasquatch Peak Forest Model (***GradientModelTreeDistributions.pptx,*** Slide 1).
2. Give each student a copy **Handout M14-1: Where Can Trees Grow on Sasquatch Peak?**
3. Have students form 12 teams. You may want to use the same teams used in Activity 13 (Mystery Trees). You will work with the "California black oak" team to demonstrate how the model works. Give each team a colored marker.
4. Explain: Each tree species grows best in certain *environmental conditions* and cannot grow at all in other conditions. The places where a species currently occurs is its *distribution.* (This is a little like the home range of an animal.) We're going to assemble a model that shows the environmental conditions in which the trees we've been studying (in Activities 12 and 13) MOST COMMONLY grow – in other words, a model of typical forest communities in our area. What are some important environmental conditions and why do they matter? Draw out the following concepts and list them on the board:
   - Elevation matters because it influences the temperature, length of summer vs. winter, amount of snow vs rain, exposure to wind, etc.
   - Slope, *aspect,* and steepness matter because they control how much direct sunlight the plants receive (and thus temperature), how much wind they are exposed to, and how rain and snow are deposited and melted/absorbed/evaporated.
   - Soil matters because it influences the nutrients available to the plant, the air available to roots, and how well water is retained.
   - Amount of moisture matters because it influences how much water is available to plants.
5. We've talked about <u>environmental</u> conditions, but plants also need certain <u>biological</u> conditions to thrive. Can you think of any? Here are a few: abundant pollinators, fungi that help roots absorb moisture ("mycorrhizae"), sparseness of competing vegetation, limited numbers of animals feeding on plant parts, limited parasites and decay fungi.
6. Explain how to interpret the graph. Spend time looking at the axes and how they are labeled: We'll use a sketch of a mountainside on the board to show where our 12 tree species are likely to live in a fictitious place called Sasquatch Peak. The data we need are in **Handout M14-1**, which shows the most common *environmental conditions* in which each species' occurs – the heart of its *distribution* - in terms of elevation and moisture. (To put it a different way, the table shows where the species COMMONLY occur, not the LIMITS of where it can POSSIBLY occur.) Thus model of the mountainside illustrates two *gradients* in environmental conditions – temperature (represented by elevation) and soil moisture.
7. Explain: This model is useful, but it is somewhat simplistic. Sites generally <u>do</u> get hotter as you go down in elevation, but that's not the only influence. What other things contribute to making a location hot? Aspect, presence of shade from other vegetation or mountains, presence of lakes or streams, wind patterns, topography – such as narrow canyons vs open slopes …. Sites generally <u>do</u> get more moist as you get close to a creek or lake, but that's not

the only influence. What other things can make the soil more or less moist? Aspect, steepness, drainage patterns, soil properties, presence of other vegetation…

Work with a couple of students to show how to illustrate a tree species' distribution on the model. Use California black oak as the example.

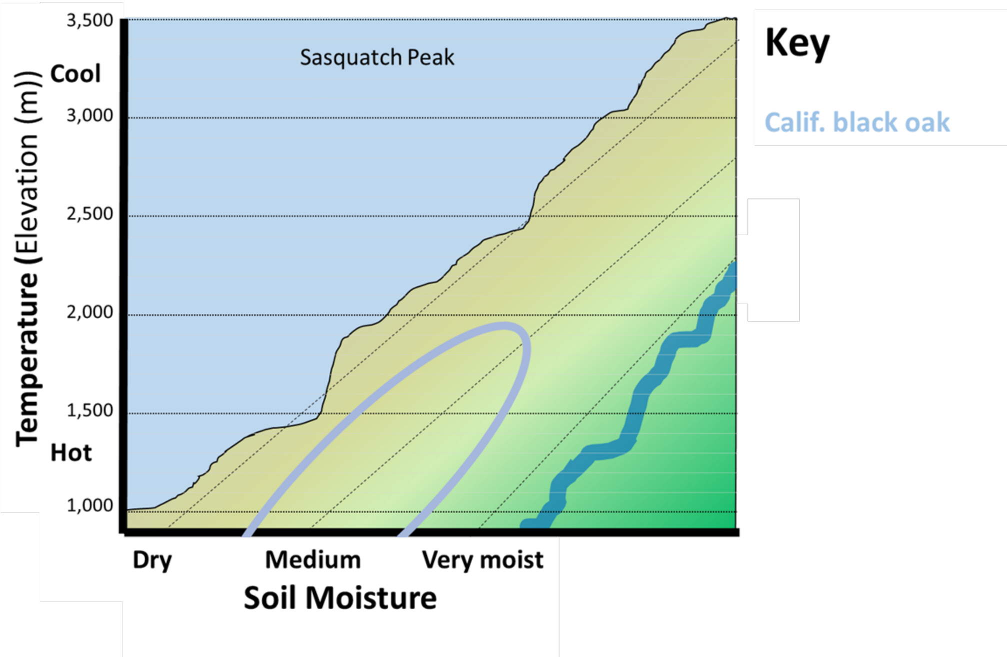
- Use this information from **Handout 14-1:**

Tree Species	Elevation (m)	Need for Moisture
California black oak	500-1800	Medium

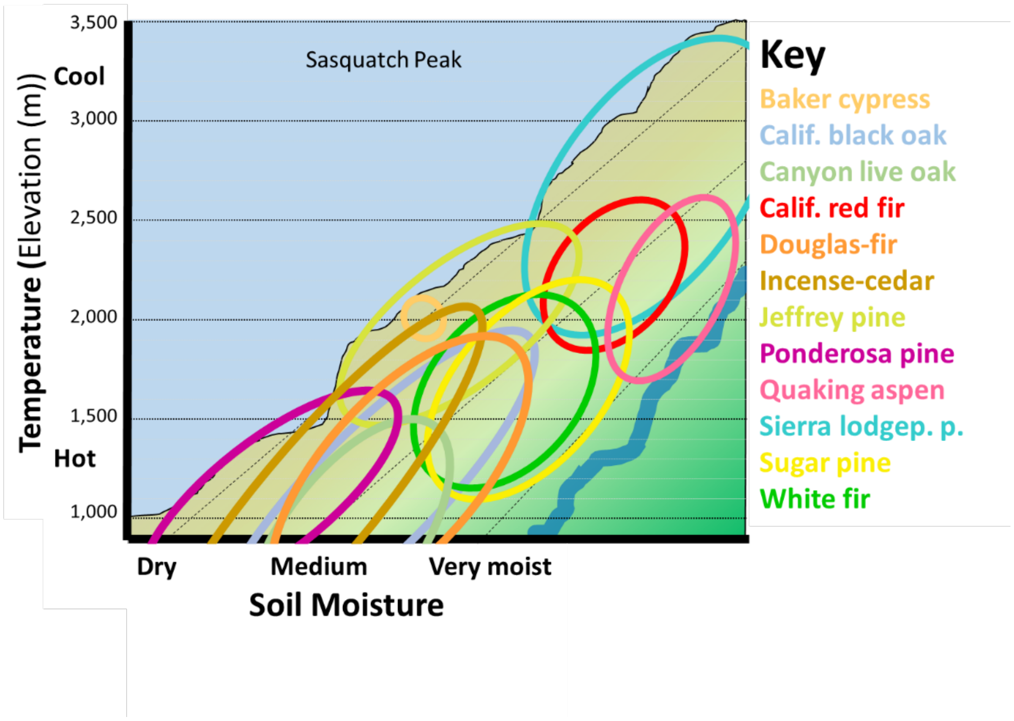
- On the graph, under "Key," use a colored marker to write "California black oak."
- Ask: What is California black oak's general elevation range? 500-1800 meters.
- Explain: The moisture gradient (shown by black dashed lines) follows the contour of the mountain. Dry sites (low moisture requirement) are near the ridge along the left edge, and moist sites (high moisture requirement) are near the creek.
- Ask: What is California black oak's need for moisture? Medium. Look at where the dashed line for "medium" soil moisture occurs on the model.
- On the model, have students mark the lowest and highest elevations (500 m and 1800 m) with a dot, placing the dots along the "medium" moisture line. (If the table lists an elevation below the range of Sasquatch Peak for any species, mark the approximate lowest elevation somewhere below the model.)
- About midway between these two dots, have students move to the left and right to mark approximate driest and wettest conditions where California black oak is likely to be common. (The table doesn't give you much information on this. Talk with the students about how wide the species' tolerance for dry and wet conditions should be.)

- Draw an oval connecting the four dots to show the approximate distribution of the species (see the example below). You can also write the species name, in small letters, inside the oval. But look out – it's going to get complicated!

Note that the specific distributions for tree species vary throughout the Sierra Nevada, so the distributions listed in this table are just one example.

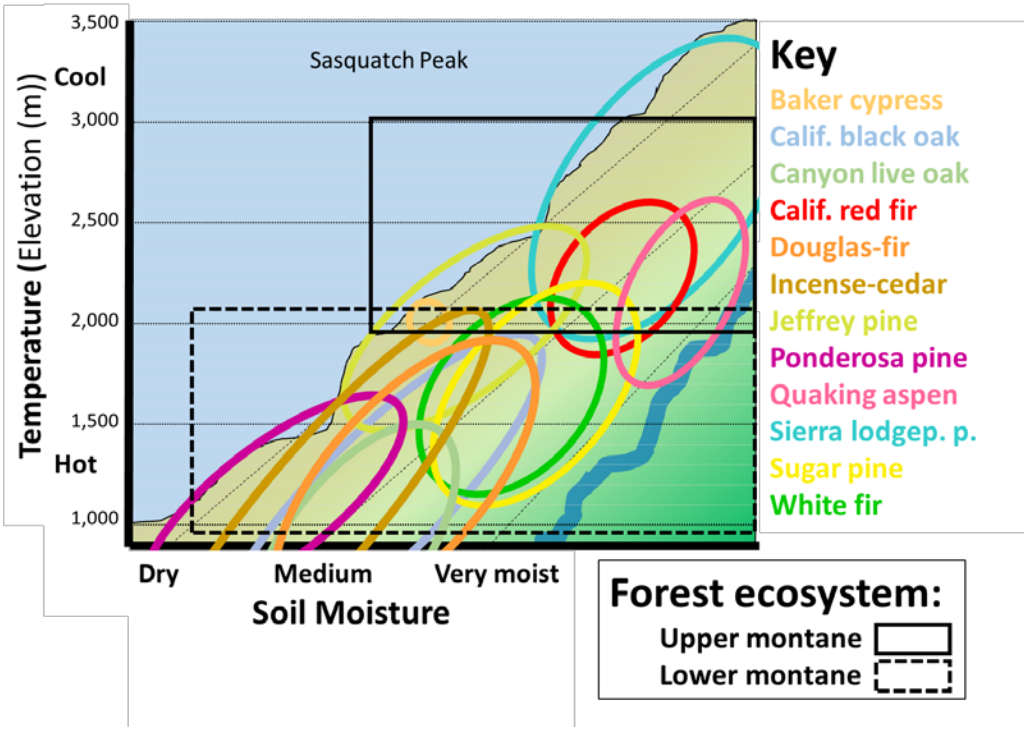


9. Ask each team to use the steps above to sketch their tree's distribution on the model.



If you have a smartboard with memory, save the model after each addition!

Explain: The model shows how complicated forest communities are – and we've included only a few species! As we learn more about fire, we're going to focus mainly on the ecology of two forest communities within this big area: lower montane and upper montane forests. Draw a rectangle around each of these regions of the model (example below).



10. Explain: The distribution of lower and upper montane forests overlap. Species common in high elevations of lower montane forests are also common in the lower parts of upper montane forests and vice versa.

11. Ask: What species are most common in lower montane forests? Ponderosa pine, incense-cedar, Douglas-fir, California black oak, sugar pine, white fir, canyon live oak. What species are most common in upper montane forests? Jeffrey pine, California red fir, Sierra lodgepole pine, and quaking aspen.

12. Discuss: This graphical *model* is useful because we can easily see which species may occur together at similar elevations within lower and upper montane forests. But remember that the boundaries shown in our model are not strict LIMITS for those tree species. Many individuals occur outside the conditions listed. For example, the model shows little or no overlap between the distributions of ponderosa pine and sugar pine. That suggests that these two species do not occur together, where in fact, they often do. LIKE ALL MODELS, THIS ONE IS HELPFUL, BUT IT IS NOT A PERFECT REFLECTION OF REALITY.

13. Explain: Over the past 100 years, the *climate* in our area has gotten warmer. In some places, it has gotten drier too. Ask: How would you describe climate, as opposed to day-to-day weather? Climate is the average patterns of weather over a long time, such as decades or centuries.

Some people say, "What you're wearing today shows the weather. What's in our closet shows the climate."

14. Ask: Since our 12 species depend on the moisture and weather conditions that we have just graphed, what would you expect them to do if those conditions change? The places where the trees can grow will also change.

15. Discuss: We can use the model to predict how *climate change* might make a location more or less favorable for our tree species. If you were in a moist area around 1,100 m with a lot of sugar pine and then, over the next 20 years, the climate got a lot hotter and drier, what species might become more common? Ponderosa pine, Douglas-fir, incense-cedar, California black oak, canyon live oak. Suppose some sugar pine seeds landed in a medium-moist area at 2,500 m elevation. Would they have much of a chance to grow up? Why or why not? Their chances would probably be better than they are now because it will probably be warmer.

16. Explain: There is a term for what happens when species move to new areas because conditions in their old homes have changed. It is called *species migration*. We're going to use our graphical model of upper and lower montane forests to make some predictions about species migration in response to climate change.

Assessment:
Give each student a copy of **Handout M14-2: Trees in a Changing Environment.** Go through the directions at the top. Tell students whether to use the graphic on the handout or on the board. Consider doing the first question together.

Evaluation: Use **Answer Key for Handout M14-2: Trees in a Changing Environment**

Handout M14-1: Where Can Trees Grow on Sasquatch Peak?

This table lists the environmental conditions where some tree species are most common on Sasquatch Peak**,** a fictitious mountain somewhere in the northwestern Sierra Nevada. The valley bottom is at 900 m elevation, but some species are able to live at lower elevations than this. The summit of the peak is at 3,500 m. The species distributions given here are generalized from data reported in the *Fire Effects Information System* (https://feis-crs.org/feis/) and *Silvics of North America**

We are studying lower and upper montane communities in the northern Sierra Nevada. We are not studying subalpine communities, which occur at higher elevations, but you may be interested to know a little about these forests: Trees that occur in subalpine communities in the Sierra Nevada include Sierra lodgepole pine, whitebark pine, western white pine, and mountain hemlock.

Tree Species	Elevations where this species is most common in the northwestern Sierra Nevada (m above sea level)	Need for moisture
Baker cypress	1900-2100	Low
California black oak	500-1800	Medium
Canyon live oak	500-1300	Medium
California red fir	1900-2600	Medium
Douglas-fir	700-1700	Medium
Incense-cedar	700-2000	Low to medium
Jeffrey pine	1500-2500	Low to medium
Ponderosa pine	500-1700	Low to medium
Quaking aspen	1600-2600	High
Sierra lodgepole pine	1900-3400	Low to high
Sugar pine	1000-2100	Medium to high
White fir	1200-2100	Medium

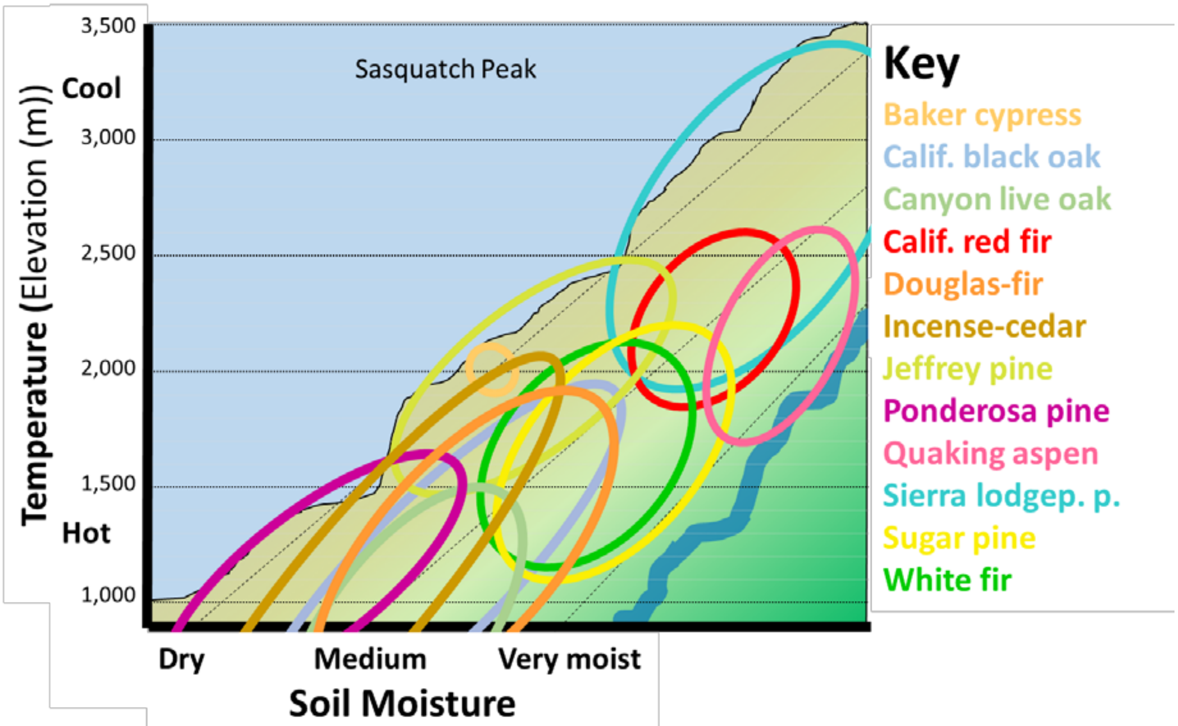
* Burns, Russell M.; Honkala, Barbara H., tech. coords. 1990. Silvics of North America. Volume 1. Conifers. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service. 675 p.

Burns, Russell M.; Honkala, Barbara H., tech. coords. 1990. Silvics of North America. Vol. 2. Hardwoods. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service. 877 p.

Handout M14-2: Trees in a Changing Environment

Name: _________________

Directions: Use this graph or the Sasquatch Peak model on the board to answer the questions.



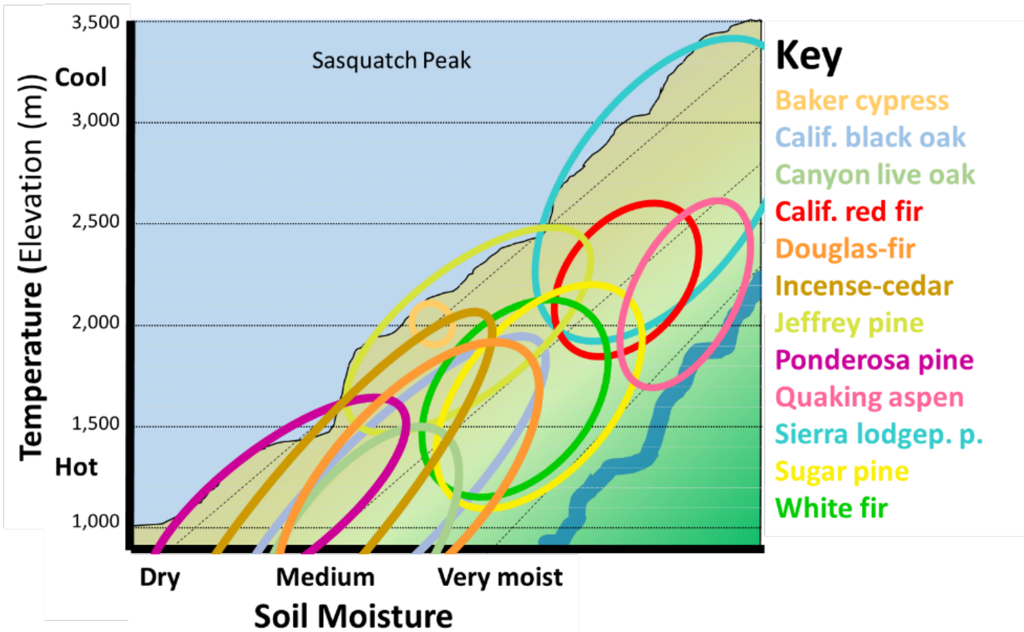
1. Suppose you are a sugar pine living at a moist area at 1,800 m elevation and your home gets a lot drier. Name two tree species that are not in your community now but might grow well there over the next 100 years: ___________________ _____________________

2. Suppose you are a California red fir living at 1,900 m elevation and your home gets a lot warmer and drier. Are your seedlings likely to survive? ___________________

3. Suppose you are a white fir living at 2,100 m elevation and your home gets a little warmer and wetter. A squirrel carries some of your seeds to 2,400 m elevation and drops them under an aspen tree. Are they likely to grow into mature trees? Why or why not?
____
____

4. Suppose you are an incense-cedar growing at 1,600 m elevation and your home gets drier. Are your seedlings likely to start growing under sugar pines? Why or why not?
____
____

Answer Key:
Handout M14-2: Trees in a Changing Environment



1. Suppose you are a sugar pine living at a moist area at 1,800 m and your home gets a lot drier. Name two tree species that are not in your community now but might grow well there over the next 100 years: Any of these: Incense-cedar, Jeffrey pine, Baker cypress

2. Suppose you are a California red fir living at 1,900 m elevation and your home gets a lot warmer and drier. Are your seedlings likely to survive? No

3. Suppose you are a white fir living at 2,100 m elevation and your home gets a little warmer and wetter. A squirrel carries some of your seeds to 2,400 m elevation and drops them under an aspen tree. Are they likely to grow into mature trees? Why or why not? Their chances are mixed. Temperatures up at 2,400 m will probably be warm enough in the future, but aspen sites are already wetter than white fir likes. If the site gets even wetter, it might be hard for white fir seedlings to thrive. In addition, the odds that ANY seed will grow into a mature tree are very low.

4. Suppose you are an incense-cedar growing at 1,600 m elevation and your home gets drier. Are your seedlings likely to start growing under sugar pines? Why or why not? Incense-cedar seedlings might indeed start growing under sugar pines because the sites where sugar pines currently grow are likely to get drier. In addition, incense-cedar seedlings are pretty good at growing under the shade of mature trees, so the sugar pines should not inhibit growth.

15. Bark and Soil: Nature’s Insulators

Lesson Overview: This activity explores the use of insulation to slow the transfer of heat through materials. Bark (on stems of trees and shrubs) and soil are two kinds of materials that insulate living things from the heat of fires.

The trunk has only 1 set of materials for this experiment, so you can do it either as a <u>demonstration</u> or a <u>station</u> where students will work in groups of 2-4.

Subjects: Science, Mathematics
Duration: Two half-hour sessions <u>or</u> one half-hour session for demonstration, then 15-minute sessions for teams
Group size: Whole class for demonstration, teams of 3-4 for followup
Setting: Indoors
New FireWorks vocabulary: *insulation*

Lesson Goal: Increase students’ understanding of heat transfer and the usefulness of insulation to slow the process of heat transfer.

Objectives:

- Students can describe how insulation affects the flow of heat through a substance.
- Students can explain how tree bark and soil can protect living tissues from the heat of fires.

ABOUT STUDENT PRESENTATIONS: If you did **Activity M11. Who Lives Here? Adopting a Plant, Animal, or Fungus**, this would be a great time for student presentations on all of the tree species. That way they can connect the concept of bark thickness to traits of particular species that they’ve been studying.

Standards:		6th	7th	8th
CCSS--ELA	Writing	4,7,10	4,7,10	4,7,10
	Speaking and Listening	1,4,6	1,4,6	1,4,6
	Language	1,2,3,6	1,2,3,6	1,2,3,6
	Writing: Science and Technology	4,7,10	4,7,10	4,7,10
CCSS--Math	Geometry	6.G		
NGSS	Structures/Properties of Matter	PS3.A		
	Energy	PS3.B		
	Engineering Design	ETS1.A,B,C		
	Natural Selection and Adaptation	LS4.C		
EEEGL	Strand 1	A,C,E,F,G		

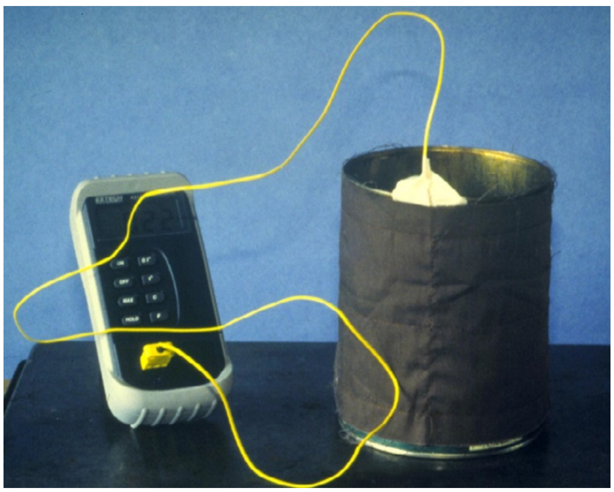
Teacher Background: This activity shows how insulation slows the transfer of heat through materials. The insulation in a home keeps it from heating up rapidly on a hot summer day and from cooling off rapidly on a cold winter night. Insulation may also slow the house’s cooling *after* a hot summer day, which is why we might open the windows and use fans to bring more cool air inside.

Nature has ways to insulate living things from the heat of wildland fires. Many trees have thick bark, which slows the transfer of heat from fire to the crucial cambium cells beneath the bark; these are the living cells that make new cells. Soil is another of nature's insulators. Soil protects small animals that stay in their underground burrows during fires. It also protects roots, buried seeds, and other underground plant parts.

In this activity, we assume that bark and soil will not burn. That assumption is not completely accurate, though. Bark can burn if it gets dried out and is exposed to enough heat. Some materials in the soil can burn, too. Soil is composed of tiny particles of rock (minerals), which are not burnable, and partly decomposed particles of vegetation and animal matter, which are burnable. When the dead, rotting organic matter is in a distinct layer on top of the mineral soil, we call it duff. Also see **Activity M10. Fire, Soil, and Water Interactions**, which explores the effects of fire on soils.

In this activity, students "model" nature's insulation by covering a surface (a model tree or model soil) with quilting materials. They use a hair dryer to simulate the heat of a fire. They heat the surface for a short time and record the temperature pattern beneath the insulation as it heats up and cools off. They may be surprised to find that, while thick insulation prevents the temperature from rising rapidly, it also prolongs the heating process and slows the cooling process when compared with thin insulation.

Materials and preparation:



- **Decide** how to do the activity. The trunk has only 1 set of materials. Unless you have additional materials, you will need to do the experiment either as a class demonstration or as a station to be used by 2-4 students at a time. We describe the "station" approach in the steps below. We suggest that you do the first iteration (0 layers of insulation) as a demonstration, then have the student teams do the second (5 layers of insulation) and third (10 layers) iterations at the station.
- **Decide** whether to model the insulating properties of tree bark or those of soil. You can discuss which one to do with the class (Step 4 below). The only difference is where you place the insulation: around a coffee can ("model" of a tree trunk) or on a table ("model" of the soil surface). After you have studied heat transfer through one material (either bark or

soil), the students should be able to discuss heat transfer through the other material. This is the last question on the handout.

- **Decide** whether to have students graph their data by hand on page 2 of the handout or use computer software such as Excel. **Note** that they must sketch hypotheses as well as observations on the graph, and that complicates the use of a computer spreadsheet.

The photo above and the directions here explain how to do the tree bark model and demonstrate the first iteration of the experiment together with the class.

Set up a table so it can be used for demonstration. Use these materials from the trunk:

- Hair dryer
- Ruler
- Digital thermometer (make sure it has a working battery and you have a spare)
- 1.5-pound coffee can/paint can/round oatmeal box (if simulating tree bark). Cover the outside with newspaper. Tape the thermocouple to the outside of the paper, about a hand's width down from the top edge.
- 3 pieces of fabric (1 piece with no quilt batting, 1 with 5 layers of quilt batting, 1 with 10 layers of batting).

Provide these materials yourself:

- Masking tape to secure thermocouple to table or "tree".
- Masking tape or clothes line clips to secure fabric to "tree"
- Stopwatch or clock (must show seconds)
- 1 copy/student or team of **Handout M15-1: Insulating Power**. Copy it 1-sided, if possible, because students will graph the data from the first page onto the graph on the second page.

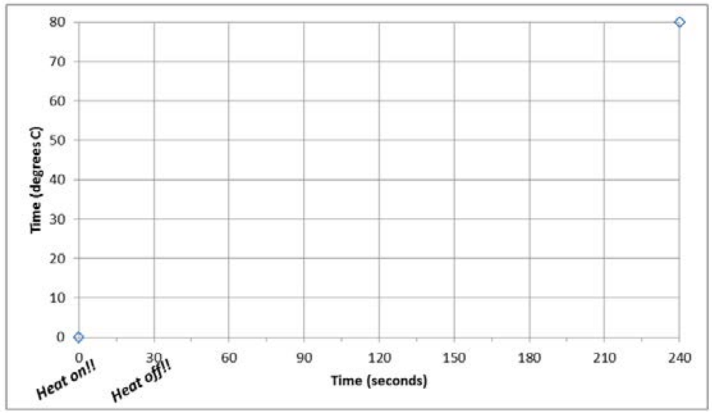
Sketch the graph for data on the board or butcher paper (**M15_EmptyGraph.pptx**).

Procedures:

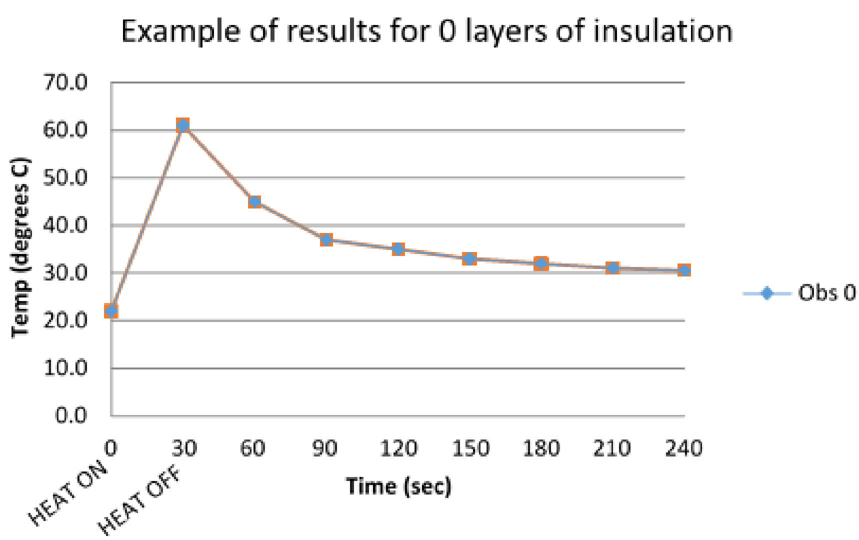
1. Ask: How do you protect yourself and your home from freezing in winter and from getting too hot in summer? We use insulation – as well as heat from wood, fossil fuels, and other sources of energy.
2. Ask: How do wildland animals, plants, and fungi protect themselves from freezing and over-heating? Their main mechanism is insulation – either something they grow themselves, like fur and tree bark, or something in the environment, like soil. If you have done **Activity M11. Who Lives Here? Adopting a Plant, Animal, or Fungus**, the students can refer to adaptations of specific organisms.
3. Explain: In this activity, we'll get a better understanding of how insulation works. What you learn here will apply to the insulation in your home just as much as to insulation of living things in wildlands.
4. Give each student or team a copy **Handout M15-1: Insulating Power.** Read the experimental questions together with the class. Decide – or tell them - which question to

investigate – the insulating effects of tree bark or soil. (Or split the class up and have different teams do the 2 different questions.)

5. **Demonstration:** Get a team of 3 or 4 students to take on the roles described in the handout. Have them practice the timing of "Heat on" and "Heat off" before actually collecting data.
6. Sketch the figure on the board (**M15_EmptyGraph.pptx**). Remind students that this is the same as what is on page 2 of their handouts. Go over the axes with the students.



7. Ask: Can they hypothesize – make a guess - at what the temperature pattern will be if they do the experiment with just a thin piece of cloth insulating the thermocouple from the heat of the hair dryer? Try to get 2-3 hypotheses and sketch them on the graph. Mark each one with "Hyp 0" for "hypothesized pattern with 0 layers of insulation." Be sure to tell them that there is ABSOLUTELY NOTHING WRONG IF YOUR HYPOTHESIS TURNS OUT TO BE INCORRECT. The point of the experiment is to learn stuff, not to prove ourselves right or wrong.
8. Set up the experiment and follow steps 1-7 on the handout. Have students record the data on their handouts under the "Obs 0" column (for "observed pattern with 0 layers of insulation").
9. Have your student helpers graph the data on the board, then have all the students graph it on their handouts. Be sure to label the line "Obs 0." It may look like the graph below.
10. Explain: Students will work at the station in teams to get the second and third hypotheses (steps 9 and 12) and sets of data (steps 10 and 13).
11. Arrange the teams and complete the experiment.



Assessment: Base assessment on completion of the handout. See the **Answer Key for Handout M15-1: Insulating Power.**

Evaluation:

	Excellent/Complete	Good	Fair	Poor/Incomplete
Question #11	-The student clearly compared/contrasted the observed and predicted results. -The student cited specific examples from the data.	-The student contrasted the observed and predicted results. -The student did not cite specific examples from the data.	-The student wrote that the predictions were (or were not) accurate. -The student did not explain why.	-The student did not address the question.
Question #14	-The student clearly compared/contrasted the observed and predicted results. -The student cited specific examples from the data.	-The student contrasted the observed and predicted results. -The student did not cite specific examples from the data.	-The student wrote that the predictions were (or were not) accurate. -The student did not explain why.	-The student did not address the question.
Question #15	-The student wrote separate responses for the 2 parts of the question (insulating properties of bark and of soil). -The student recognized the importance of bark as protection of cambium from surface fire and soil as protection of buried roots and seeds from surface and ground fire.	-The student responded to only 1 of the 2 parts of the question OR -The student did not specify the kind of fire that thick bark/deep soil protect against.	-The student responded to only 1 of the 2 parts of the question AND -The student did not specify the kind of fire that thick bark/deep soil protect against.	-The student did not answer the question directly.

Handout M15-1: Insulating Power

Names: ____

Here are two experimental questions:

- Can thick bark insulate the phloem, cambium, and xylem of a tree from fire's heat?
- Can soil insulate seeds and roots from fire's heat?

Find out by measuring and graphing the pattern of temperature change beneath different amounts of insulation.

Get organized:

- TIMER calls out 15-second intervals and "Heat on/off!"
- HEATER runs hair dryer.
- OBSERVER watches thermometer, calls out temperature.
- RECORDER writes down temperature observations.

Set up the experiment:

Set up the thermometer so the OBSERVER can see it.
For a soil model: Tape the thermocouple wire to a table top.
For a tree trunk model: Tape the thermocouple wire to the surface of an empty coffee can or oatmeal box, covered with paper.

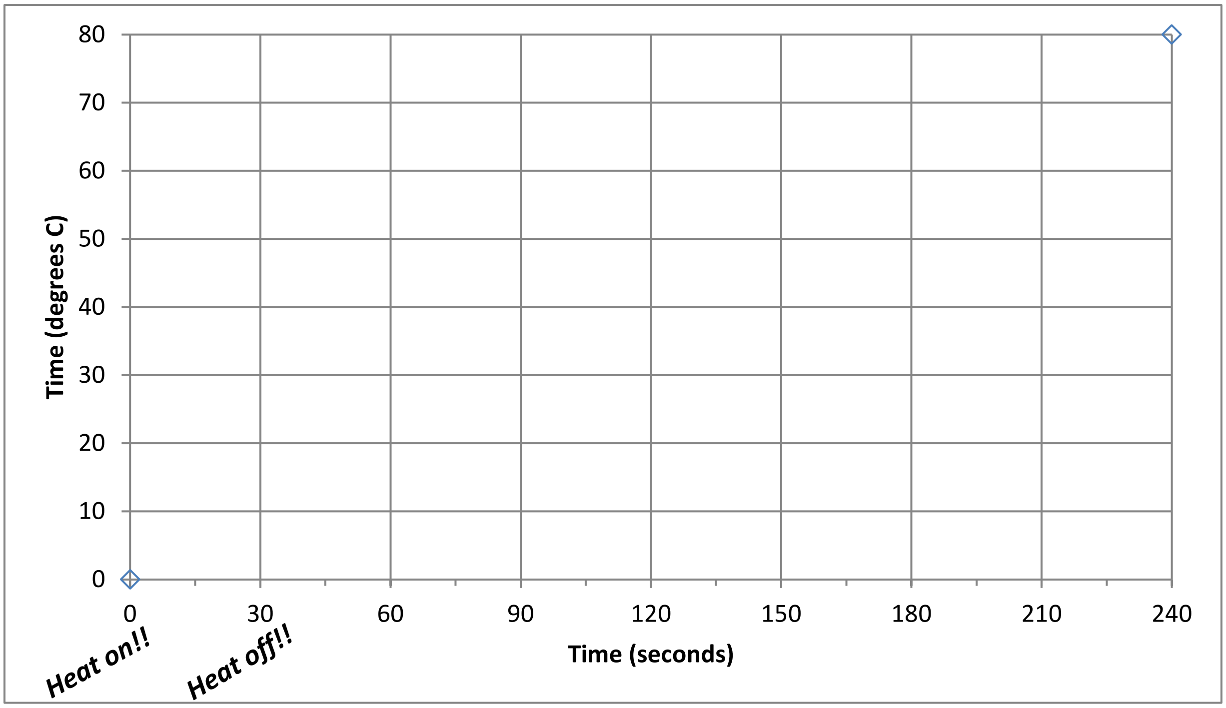
Do the first experiment with just a thin piece of fabric covering the thermocouple (tape or clip the fabric in place). Do the next experiments with 5 layers of insulation (Steps 9-11 below) or 10 layers of insulation (Steps 12-14).

Time (seconds)	**Temperature (ºC)**		
	0 layers (Obs 0)	**5 layers (Obs 5)**	**10 layers (Obs 10)**
0 – HEAT ON			
15			
30 – HEAT OFF			
45			
60			
75			
90			
105			
120			
135			
150			
165			
180			
195			
210			
225			
240			

Procedure:

1. HEATER, position the hair dryer about 20 centimeters from the table or coffee can, pointing at the thermocouple tip (which you can't actually see now because it's under cloth).
2. OBSERVER, turn the thermometer on. Set it to degrees Celsius. Report the temperature.
3. RECORDER, write down the temperature at "0" seconds using the appropriate column in the table for the layers of insulation being tested (0, 5, or 10).
4. TIMER, call out "Zero, heat on!" HEATER, turn the hair dryer to "high."
5. TIMER, call out "Fifteen." OBSERVER, report the temperature. RECORDER, write it down.
6. TIMER, call out "Thirty. **Heat off**!" **HEATER, turn the hair dryer off**. OBSERVER, call out the temperature. RECORDER, write it down.
7. Every 15 seconds until 4 minutes have passed: TIMER, call out the time in seconds. OBSERVER, report the temperature. RECORDER, write it down.

8. Graph your results. Connect the points. Label it “Obs 0,” meaning “observed pattern with 0 layers of insulation.”



9. What do you think will happen if you add 5 layers of insulation? Use a pencil to draw the temperature pattern you expect in the graph above. This line shows your **hypothesis**. Label the line “Hyp 5” to indicate “hypothesized pattern with 5 layers.”

10. Use the set of insulation with 5 layers and repeat the experiment (steps 1-7). On the graph above, plot your data and label the line “Obs 5” to indicate “observed pattern with 5 layers.”

11. Compare your observed results with the results you predicted in step 9. Use specific examples from your data and use complete sentences to describe how accurate your predictions were.

12. What if you add 5 more layers of insulation, for a total of 10 layers? On the graph, pencil in a line to show your hypothesis and label it “Hyp 10.”

13. Use the thickest set of insulation (10 layers). Repeat steps 1-7. On the graph above, plot your data and label the line “Obs 10.”

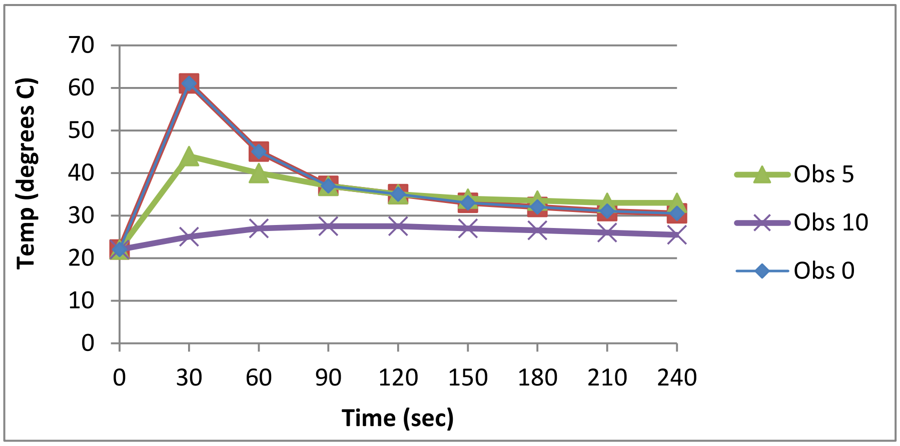
14. Compare your observed results with the results you predicted. Use specific examples from your data and use complete sentences to describe how accurate your predictions were.

15. Can thick bark really protect a tree? Can soil really protect underground seeds and roots? Answer both questions regardless of which question you tested. Using complete sentences, explain why or why not.

Answer Key for Handout M15-1: Insulating Power

A completed data table and graph might look like this – except we did not insert hypothesized lines.

		Temperature (° C)		
		0 layers	5 layers	10 layers
Time (sec)		Obs 0	Obs 5	Obs 10
0	HEAT ON	22.0	22.0	22.0
30	HEAT OFF	61.0	44.0	25.0
60		45.0	40.0	27.0
90		37.0	37.0	27.5
120		35.0	35.0	27.5
150		33.0	34.0	27.0
180		32.0	33.5	26.5
210		31.0	33.0	26.0
240		30.5	33.0	25.5



15. Can thick bark protect a tree from all 3 kinds of wildland fire – ground, surface, and crown? Can soil really protect underground seeds and roots from all 3 kinds of fire? Answer both questions regardless of which question you tested. Using complete sentences, explain why or why not.

Thick bark can protect a tree from surface fires because it can keep the cambium layer from heating up to lethal temperatures. Of course, the longer the fire burns, the deeper the heat will penetrate into the bark, phloem, cambium, and xylem. Thick bark does not insulate leaves or the buds at the tips of branches, so it cannot protect a tree from crown fire. Thick bark cannot protect a tree from ground fire either. If a fire smolders in the duff around the base of the tree, it can kill the tree's roots, and it can kill the cambium at ground level.

Thick soil can protect underground seeds and roots from surface fire because it can keep them from heating up to lethal temperatures. Of course, the longer the fire burns, the deeper the heat will penetrate. But if there is a lot of burnable material (like duff) on top of the soil or mixed in with it, and if that material burns, the resulting ground fire can kill buried seeds and roots – and even burn them up. So thick soil may not protect buried seeds and roots from ground fires, and it does not offer any protection against crown fires.

16. Buried Treasures: Identifying Plants by their Underground Parts

Lesson Overview: Students examine specimens of nine plant species – grasses, wildflowers, and shrubs – and use a dichotomous key to identify them based on their "buried treasures" – underground parts that can sprout after fire and grow new plants.

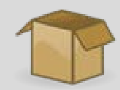
Lesson Goal: To increase student understanding that plants have many ways to survive wildland fire and/or reproduce successfully after fire, including underground structures.

Subjects: Science, Mathematics (logic), Reading

Duration: One to two half-hour sessions

Group size: Whole class, possibly working in teams

Setting: Classroom



New FireWorks vocabulary: *bulb, dichotomous key, fire dependent, lignotuber, rhizome, root crown, top-kill*

Objectives:

- Students can recognize different kinds of underground plant parts that can sprout new plants (bulb, rhizome, root crown, lignotuber) after fire.
- Students can use a dichotomous key to determine the species of each one.

ABOUT STUDENT PRESENTATIONS: If you did **Activity M11. Who Lives Here? Adopting a Plant, Animal, or Fungus**, this would be a great time for student presentations on all of the herb and shrub species – and possibly also on quaking aspen. That way they can connect the concept of "buried treasures" to the underground parts of particular species that they've been studying.

Standards		Sixth	Seventh	Eighth
CCSS	Speaking and Listening	1,2,6	1,2,6	1,2,6
NGSS	Structure, Function and Information Processing	LS1.A		
	Growth, Development and Reproduction of Organisms	LS1.B		
	Engineering Design	ETS1.B,C		
	Natural Selection and Adaptations	LS4.B, LS4.C		
EEEGL	Strand 1	A, C, E, G		

Teacher Background: People are generally familiar with the above-ground appearance of plants, and they know that most plants have roots underground, but they don't think much about plants' other underground parts – unless it is in terms of food! Yet plants have many kinds of "buried treasures" that enable them to survive fire and thrive afterward. This activity covers only a few kinds of plants and buried treasures, which we selected because they are very important members of montane Sierra Nevada plant communities. They all regenerate from underground parts after fire, and some of the require fire to regenerate. We call these *fire dependent* species.

Seeds are one kind of buried treasure. If they have a very hard covering and are located deep enough in the soil that they do not burn, they are able to grow new plants after fire. In fact, the seeds of the deer brush, sticky whiteleaf manzanita, and mountain whitethorn included in the trunk (plants 3, 4, and 9) can only germinate with heat. Sticky whiteleaf manzanita is a good example of a fire dependent species.

Other kinds of buried treasure enable plants to sprout new growth after their above-ground parts are removed. Buried roots, leaves, stems, and rhizomes account for the ability of perennial plants to survive cold winters, grazing, fire, and other forces that kill off their aboveground parts. (This is called *top-kill*.) All of these buried treasures work because they contain tiny buds with undifferentiated cells ("meristem tissue," which is like stem cells in animals). Meristem cells have the ability to sprout and develop a new stem and leaves, but they are suppressed by hormones produced in the plant's above-ground parts. When the above-ground parts are removed, the buds are no longer suppressed, so they begin to grow, develop, and form a new stem.

Buried treasures are plant adaptations to fire. Other plant adaptations to fire in the Sierra Nevada include the thick bark of mature ponderosa pines, Jeffrey pines, sugar pines, and firs (explored more fully in **Activity M15: Bark and Soil: Nature's Insulators**) and the serotinous cones produced by Baker cypresses and knobcone pines. Students may have learned about serotiny from the student presentation on Baker cypress in **Activity M11: Who Lives Here? Adopting a Plant, Animal, or Fungus**. If you would like to explore the topic in more detail, you may use this activity from the Elementary curriculum: **Activity E11: Recipe for a Baker Cypress grove: Cone Serotiny.**

In this activity, students learn the names of several kinds of buried treasures: *bulbs, root crowns, lignotubers,* and *rhizomes*. Other buried treasures not covered in this activity include *corms, caudices,* and *taproots*. Students use a dichotomous key to identify eight plant species that thrive after fire in the wildlands of the Sierra Nevada. Most keys rely on plants' above-ground characteristics as criteria for identification, but this key is based mainly on plants' underground parts.

Materials and preparation:

- Download for projection: ***M16_BuriedTreasure.pptx***.
- Print 1/student: **Handout M16-1: Underground Plant Parts** and **Handout M16-2: Dichotomous Key**.
- Find the 8 plant specimens in the trunk. Each species' buried treasure is noted in parentheses here:
    1. quaking aspen (spreading roots)
    2. Sierran gooseberry (root crown)

3. deer brush (root crown)
4. mountain whitethorn (lignotuber)
5. Ross's sedge (root crown/sometimes short rhizomes)
6. mariposa lily (bulb)
7. wavyleaf soap plant (bulb)
8. bracken fern (rhizomes)
9. sticky whiteleaf manzanita (seeds only)

- Keep #9, (sticky whiteleaf manzanita) out to show the class a species with seeds that require fire (some also sprout).
- Set up the other eight specimens at stations around the room so students can circulate to identify them.

Procedure:

1. Give students five minutes to draw a plant that they have seen near their house, school, or outside of their town. After students are finished, have a few of them show their sketches. Did anyone sketch underground parts? If they did, give them kudos!

2. Write "*Buried Treasures*" on the board. Ask: What parts of plants are found underground? List them on the board. Students will name roots and perhaps seeds. Encourage them to recall underground "vegetable" parts, such as onions, radishes, and potatoes. We think of them as foods, but for the plant they are ways to store energy and regenerate. Although students may not know the technical names for these plant parts, they may be surprised at how familiar they are with plants' buried treasures.

3. Explain: Most kinds of plants reproduce from seed, and some have seeds that require heat to begin developing. Show them the specimen of Plant 9, sticky white leaf manzanita. Its seeds have very hard coats, which will not open – and cannot begin to grow - until they are cracked open by heat. If a plant or animal *needs* fire, we call it a *fire dependent* species.

4. Explain: Some plants can also sprout new growth from their roots. Quaking aspen is an example. (They already identified aspens if they did **Activity M13: Tree Identification: Figure out the "Mystery Trees."**)

5. Explain: In today's class we'll look at several kinds of "buried treasures" – plant parts that can generate new growth and new plants after their above-ground parts have been removed or killed – that is, *top-killed* – by fire, grazing, winter's cold, and other disturbances. You'll need to know about these plant parts to identify the plant specimens that are set up at stations around the room.

6. Give each student a copy of **Handout M16-1: Underground Plant Parts.**

7. Project ***M16_BuriedTreasure.pptx,*** which shows 4 kinds of buried treasures (see the slides below). Stop at each slide and have students write the term on the handout, sketch what it looks like, and define it.

Slides from *M16_BuriedTreasure.pptx*

Slide 1

Bulb: structure made of layers of tissues that are actually underground leaves

Photo by Jonathunder

https://commons.wikimedia.org/wiki/File%3AOnionBulbRoots.jpg

By Jonathunder (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0) or GFDL (http://www.gnu.org/copyleft/fdl.html)], via Wikimedia Commons

Slide 2

Lignotuber: a woody swelling at ground level, from which dormant buds can develop

Photo by Casliber

https://commons.wikimedia.org/wiki/File%3ALambertiaformLCNP.JPG

By Casliber (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

Slide 3

Rhizome: a horizontal, creeping underground stem, which may be woody or string-like

Photo by Rasbak

https://commons.wikimedia.org/wiki/File%3AChamerion_angustifolium_rhizomes%2C_wilgenroosje_wortelstokken.jpg

By Rasbak (Own work) [GFDL (http://www.gnu.org/copyleft/fdl.html) or CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

Slide 4

Root crown: The place where the root and the stem of a plant meet. In some species, the root crown contains buds that can sprout if the plant is top-killed.

Photo by Mark A. Dimmitt © 1969 ASDM

http://www.desertmuseumdigitallibrary.org/public/detail.php?id=ASDM09616&sp=Chaparral%20-%20Californian

Photographer: Mark A. Dimmitt
ID: ASDM09616
Copyright: © 1969 ASDM

8. Review/Explain: Fires top-kill many plants, yet many of them can grow back from buried treasures – and they often grow larger and produce more seeds than before the fire. Furthermore, they may produce completely new plants from the same underground parts.

9. Now we will use a *dichotomous key* to identify some of the shrubs, wildflowers, and other plants that grow in the Sierra Nevada. We'll identify them based on the buried treasures that enable them survive and even thrive after fire.

Assessment:

- Give a copy of **Handout M16-2: Dichotomous Key** to each student.
- Explain: All of these wildland plants are champions at surviving and sprouting from their buried treasures after fire. You will use their buried treasures to identify the species of each sample.
- Explain these concepts for how to use the key:
  - For every plant specimen, start at the beginning (left side) of the key. If you start in the middle, you can't be certain that you got the identification correct.
  - When you think you have identified the specimen, write its number in the appropriate box in pencil.
  - Finalize your numbers only after you have identified all of the specimens.
  - Identify each species, write the correct number in the box with that plant's name, and move on to the next specimen. You may re-examine any specimen and change your mind until we finish the activity.

Have a few students start at each station.

Evaluation:	Excellent	Good	Fair	Poor
	Student identified 7-8 species correctly	Student identified 5-6 species correctly	Student identified 3-4 species correctly	Student identified 3 or fewer species correctly

Handout M16-1: Underground Plant Parts

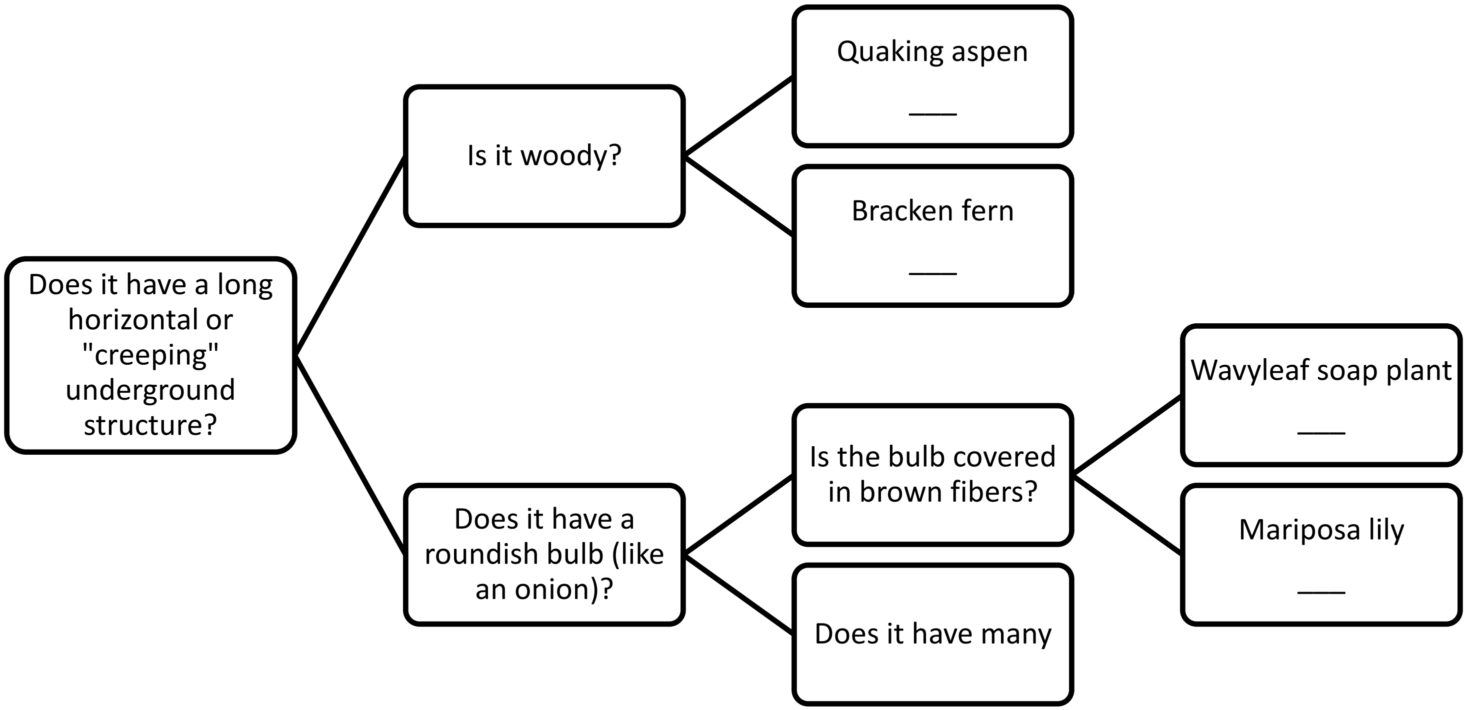
Name: ______________________________

Term	Draw	Define

Handout M16-2: Dichotomous Key

Name____________________

Please note: This is a place holder! I did not have the specimens to create the key. We will complete the key once we have the specimens.



Unit VI.
Fire History and Succession

In this unit, students learn about the history of fire in the lower and upper mixed conifer forests of California.

In the first lesson of the unit (Activity 17), students focus on the scars left on tree trunks by *low-severity fires.* They learn how fire scars are formed. They examine photos and tree growth rings to find out how often fires have marked an individual tree. Then they pool the data from several trees to describe the history of low-severity fire for a whole forest.

In the second lesson of the unit (Activity 18), students focus on tree ages as recorded in *increment cores*. With information from increment cores, they can determine when the most recent *stand-replacing fire* occurred. With information on the frequency of both low-severity and stand-replacing fires, they can describe the *fire history* of a specific kind of forest and thus begin to understand the historical and current *fire regimes* of mixed-conifer forests in the Sierra Nevada.

In the third lesson of the unit (Activity 19), students integrate their knowledge about individual organisms' relationships with fire and fire regimes. They create a drama that demonstrates how montane forests of the Sierra Nevada change over time, with and without fire.

17. Fire History 1: Long Stories Told By Old Trees

Lesson Overview: Students study the scars left by low-severity fires on tree trunks – how these scars form, how many have marked a tree, and how many years went by between fires. With this information, they can describe the history of low-severity fire for that tree. With data from the whole class, they can describe the history of low-severity fire for a whole stand or forest.

Subjects: Reading, Writing, Speaking and Listening, Math, Science

Duration: Two or three 30-minute sessions

Group size: Whole class, working singly or in teams

Setting: Classroom

New FireWorks vocabulary: *dendrochronology/ dendrochronologist, fire scar, fire interval, growth ring, low-severity fire, stand-replacing fire, stand history diagram*

*This lesson can be done without a trunk if you print the photo posters and skip looking at a real fire-scarred tree cookie

This activity has 3 parts:

I. **Introduction to fire history research**, in which you examine a real specimen of a fire-scarred tree cross section ("tree cookie") as a class.

II. **Living Model of Fire Scar Formation**, in which students learn how fire scars form by building a living model that shows a tree's response to surface fire. This is followed by the first part of the assessment, completion of **Handout M17-1. A Tree's Story.**

III. **Telling the Story of a Whole Forest**, in which students pool their fire history data on 17 individual trees and analyze the resulting diagram to better understand the history of low-severity fire in Sierra Nevada montane forests.

Lesson Goals: Students understand that some trees can survive frequent low-severity fire. They can describe the history of low-severity fire for a specific tree, and they can describe the history of low-severity fires for a stand or forest.

Objectives:

- Students can identify tree growth rings and fire scars.
- Students can describe the history of low-severity fire for the tree.
- Students can use their data to make inferences about the history of low-severity fire in a forest.

Standards:		6th	7th	8th
CCSS	Speaking and Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Writing	1,4,10	1,4,10	1,4,10
	Writing: Science and Technology	3,4,7,9,10		
NGSS	Structure, Function, and Information Processing	LS1.A		
	Natural Selection and Adaptation	LS4.C		
	History of Earth	ESS2.C		
EEEGL	Strand 1	A,B,C,E,F,G		
	Strand 2.2	A		

Teacher Background: Fire has been a part of the history of most forests in North America for thousands of years. Tree *growth rings* and *fire scars* tell about a forest's fire history. The kind of fire that scars trees is called *low-severity* fire. Many surface fires have low severity, but not all of them. Some surface fires and all crown fires produce so much heat that they kill the crown, cambium, and/or roots of most of the trees. These are called *stand-replacing fires* because a whole new generation of trees must develop to replace the ones killed by fire. You can learn more about stand-replacing fires in **Activity M18: Fire History 2: History of Stand Replacing Fire**.

This activity begins with the whole class studying a real fire-scarred tree cookie collected from the Plumas National Forest and describing its fire history. (Each FireWorks trunk has its own unique cookie, collected by Tadashi J. Moody and others (2006) for a paper published in the journal *Fire Ecology*[1]*.* This paper is included in your curriculum materials - **MoodyEtAl2006_FireHistPlumas.pdf**.) Then the class creates a model to learn more about how a fire can scar a tree without killing it and how to identify fire scars. Then they do the first part of the assessment: working individually or in teams to describe the fire history of a single tree cookie collected from the eastern slope of the Sierra Nevada by Nicole Vaillant and Scott Stephens (2009)[2]. (They use photos of the tree cookie – called "photo posters," not the real wood.) Finally, they pool their results and examine the history of low-severity fires across the forest area sampled for the study.

Other information on fire scars and wood:

- After a tree has one fire scar, it is more vulnerable to further scarring because that region of the trunk has no insulating bark and it may contain a lot of pitch, which can be ignited easily.
- Trees do not "heal" in the same way animals do: The dead cambium does NOT recover to become functioning tissue again, as our skin and bones can do after an injury. However, the

[1] Moody, Tadashi J.; Fites-Kaufman, JoAnn; Stephens, Scott L. 2006. Fire history and climate influences from forests in the northern Sierra Nevada, USA. Fire Ecology. 2(1): 115-141.
[2] Vaillant, Nicole M.; Stephens, Scott L. 2009. Fire history of a lower elevation Jeffrey pine-mixed conifer forest in the eastern Sierra Nevada, California, USA. Fire Ecology. 5(3): 4-19.

dead wood may gradually be covered by new cambium and new bark that grows in from the sides. "Trees do not *heal*, they *conceal*."

- Fire scars form most often on the uphill side of tree trunks. Why? A hot vortex of flame forms on the forward side of any obstacle in the fire's path. Since fires often spread uphill, the uphill side of the tree trunk tends to get more of this vortex heat than the other sides. Also, there is usually more debris on the uphill side since branches, cones, litter, and duff accumulate there instead of rolling downhill.
- Why is some of the wood in a tree cookie dark while other areas are very light? The outer wood (*xylem* or *sapwood*) is often lighter than the inner wood (*heartwood*) because it is filled with water and minerals. The dark wood is usually in the center and in damaged areas of the tree trunk. It is dark because it is filled with pitch rather than sap. Pitch helps a tree survive injury because it can keep fungi from spreading throughout the wood. The pitch-filled heartwood cells are not alive, but they provide structural support for the tree.
- Other unusual marks in wood include patches of rot, holes made by wood-boring beetles, checks (radial cracks where the wood has dried and split), and branch scars (where a branch originated or a broken branch stub was covered by later growth).

Materials and preparation:

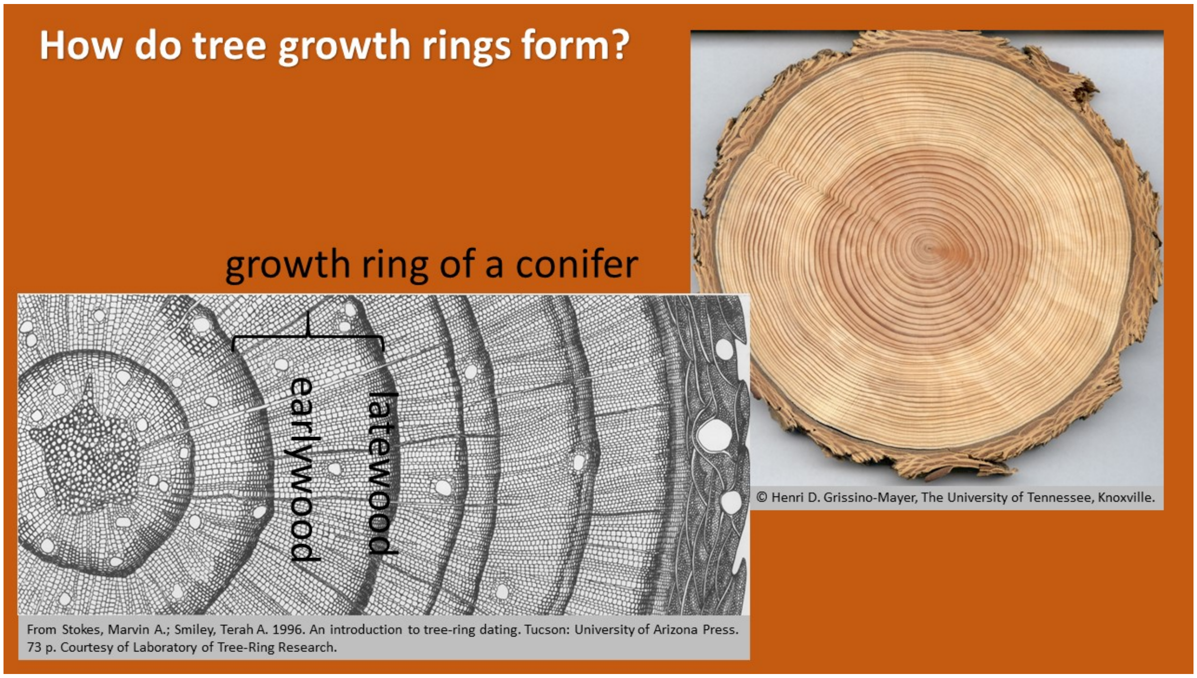
1. Make 1 copy/student or team of **Handout M17-1. A Tree's Story**.
2. Find a piece of black plastic or cloth about 25 cm inches wide and about 1.0 m long.
3. Download ***HowGrowthRingsForm.pptx***
4. Download ***FireScars.pptx***
5. Download **MoodyEtAl2006_FireHistPlumas.pdf**.
6. Download **VaillantStephens_2009.pdf**.
7. Find in the trunk or produce your own:
   - small whisk broom (or make a fan out of orange construction paper)
   - 1-2 Hand lenses
   - Real fire-scarred tree cookie with the key that shows its unique fire history. (Each trunk has its own real fire-scarred cookie and key.)
   - Tree cookie photo posters (a set of 17, or download online and print)
   - The ***FireWorks Cookie Book – Low-severity Fire on the Sagehen Experimental Forest*** (in the trunk and also here). This document contains solutions to **Handout H17-1: A Tree's Story** for ALL OF THE PHOTO POSTERS IN YOUR TRUNK.

Provide one cookie photo poster for every 1-2 students. Students will use the photo posters to describe the fire history of individual trees. Then they will pool their data to describe the history of low-severity fire throughout the area of the study. Each photo poster is labeled with the tree's species and an identifying number and contains a table showing the dates of the earliest and most recent growth rings plus the dates of all fire scars on that tree cookie. The ***Cookie***

Book contains answers to **Handout 17-1: A Tree's Story** for all of the photo posters in your trunk.

Procedure, Part I: Introduction to Fire History Research

1. Display ***HowGrowthRingsForm.pptx***. Review these concepts (which they are probably familiar with already):



   - Trees generally produce 1 *growth ring* per year, so you can estimate a tree's age by counting its rings.
   - A ring consists of a wide row of large, thin-walled, light-colored cells plus a narrow row of tiny, dark-colored cells.

2. Ask: Do you think every tree has a perfect, undamaged cross section like those shown here? Of course not! Lots of things, including fire, can damage the tree's protective bark, kill the cambium, and even destroy part of its wood. These events may not kill the tree, but they do create scars in the wood.

3. Explain: In this activity, we'll learn about the history of *low-severity fires* in the Sierra Nevada. Fires are *low-severity* if they kill very few of the mature trees in a forest. They are *stand-replacing* if they kill most of the mature trees (and make room for the forest to *replace* itself with young, new trees). Many surface fires are low-severity fires, but some produce so much heat that they kill most of the trees, so they are stand-replacing.

4. Show students the real fire-scarred tree cross section from your trunk. Explain: It is sometimes called a "tree cookie." It was collected in a study of the fire history of montane ecosystems in the Plumas National Forest. The scientists used *dendrochronology* (the study

of tree growth rings) and *fire scars* to figure out how often low-severity fires have occurred in this forest over the past 400 years.

5. Show the class (project) the first page of **MoodyEtAl2006_FireHistPlumas.pdf**, then pages 4 (map of the study location) and 7 (photo of one of the tree cookies used in the study). Explain: We're going to use the same techniques as theirs to figure out the history of low-severity fire in a similar kind of forest further south, the Tahoe National Forest. We're going to analyze fire scars on photos of tree cookies. We'll use them to figure out the time between fires. The number of years between 2 surface fires is called the *fire interval.*

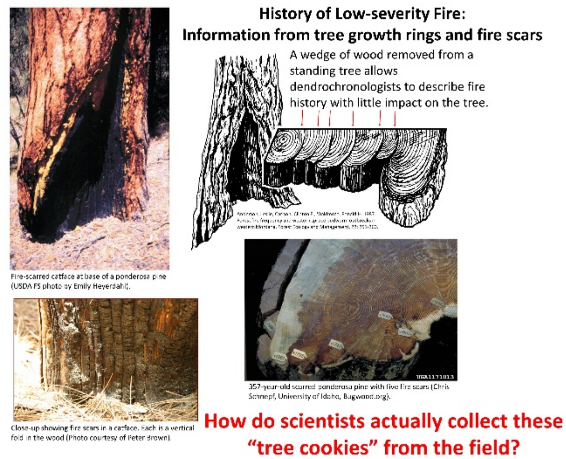
6. Display Slide 1 from ***FireScars.pptx.*** (All slides are shown below.) Ask: How can you tell if damage on a tree trunk was caused by a fire? Using Slide 1 and the fire-scarred tree cookie from your trunk, discuss the identifying characteristics of fire scars:
   - Fire scars originate from the ground. They don't start part-way up the tree trunk.
   - Viewed from the front of the tree, fire scars are roughly triangular in shape, wider at the base and narrower at the top.
   - If many fires have scarred a tree, the scars look like a series of vertical folds on the blackened wood. (OPTIONAL: You could add that a tree's first fire does not char the wood, but later ones do. See the **Teacher Background** above.)
   - Viewed from the top of a tree cookie, a fire scar looks like an indentation from the outside edge of the wood. The scar follows along a growth ring part-way into the wood. (OPTIONAL: Integrate some geometry: If you think of a growth ring as the circumference of a circle, then you know that a fire scar cannot be on a radius coming out from the center. Any radial marks are from other sources, such as branch scars or "checks" (crack) in the dried wood.)
   - If you have a whole (roundish) tree cookie, you can see that fire scars are somewhat symmetrical – that is, new wood curls over the damaged wood from both sides of the damaged area. If you don't watch out for this, you may count each fire twice!

7. Explain: If you're looking at a whole tree cookie – that is, a nearly round one – it was probably taken from a stump or from a dead, fallen tree. If you're looking at a narrow or wedge-shaped cookie, it was probably taken from a standing tree, living or dead. Scientists do not cut trees down to study their fire scars.

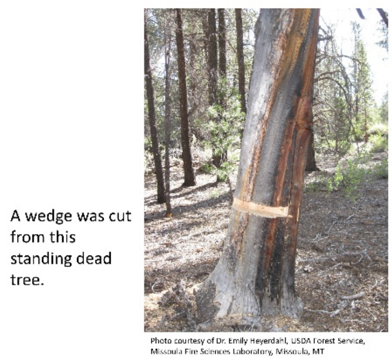
8. Show the rest of the ***FireScars.pptx*** to see how fire scars are sampled

Slides from *FireScars.pptx*

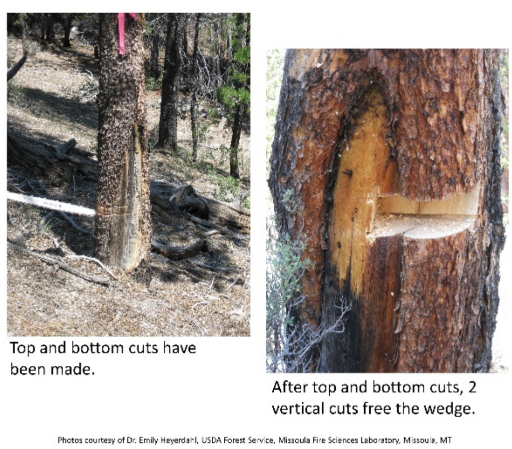
Slide 1



Slide 2



Slide 3



Slide 4

Side 5

Slide 6

Procedure, Part II: Living Model of Fire Scar Formation

9. Explain: The class will construct a living model to show how fire scars are formed. Follow these directions or see a demonstration online at: *www.youtube.com/watch?v=MyFBYQh_S_M*

a) One student holds his/her arms out in a circle, forming a ring that represents the tree's cambium – that is, the sheath of living cells right under the bark that form xylem and phloem – and are essential for continued growth.

b) Ask the students to imagine that the "tree" is facing uphill and a low-severity surface fire is coming up from behind it, running uphill. Select a student to represent the surface fire, using the whisk broom to burn from the "downhill" side of the tree around it to the other side, then continuing "uphill" and away from the tree.

c) Interview the "tree." Ask how the fire felt. Point out that the tree is still alive, since it is talking, so this must have been a low-severity surface fire!

d) Tell the students that the fire was hot enough to kill a portion of the cambium – right where the student's hands are. Drape your piece of black cloth or plastic over the "killed" section to remind the class that these cells are dead and cannot produce a new growth ring next year.

e) Ask: Why is there more damage on the uphill side than the downhill side? Fires form a hot vortex of flame as they go around an obstacle and the flames come together from the two sides. Also, there is often more debris on the uphill side, since branches, cones, and litter accumulate there instead of rolling downhill. The duff is generally deeper on the uphill side as well.

f) Get two more students to help, one standing on each side of the model tree. They are the next year's growth ring. Each places a hand against the arm of the "tree," right at the edge of the area "killed" by fire (which is now covered in black). New cells can't grow out of the black area because it has no living cambium.

g) Get two more students to represent the tree's growth in the second postfire year. They place their hands on top of those of the last two students. Their hands can overlap the black cloth a little, curling around the fingertips that represent last year's growth. This shows that the cells at the edges of the scar are dividing both outwardly and laterally, so they are beginning to grow over the scar. This is how the "bubble" of growth forms at each edge of a fire scar.

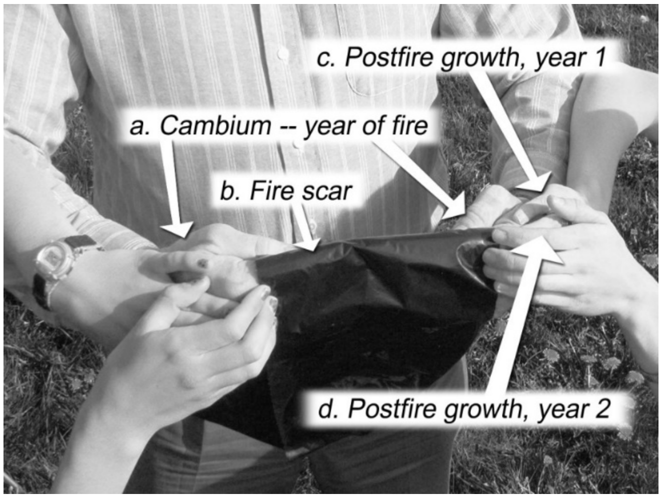


Figure M17-01. Students build a living model of tree cambium and fire scar with their hands.

h) Use more pairs of students to represent more years of growth after fire so they can see how the new wood curls over the old scar.

i) Explain: Sometimes the growing wood from the two sides of the fire scar comes together and bark forms over the scar, hiding it from everyone who doesn't know about fire scars. To those “in the know,” like this class, that caved-in look on the uphill side of the tree suggests a history of low-severity fires.

10. Pass out copies of **Handout M17-1. A Tree’s Story**. Explain: You will use the handout to figure out the fire history of a specific tree. You won’t work with the actual sample, but instead you’ll have high-resolution photos of tree cookies – along with the results recorded by the scientists when they examined the wood under a microscope. After we have the data on individual trees, the class will pool data to figure out what the pattern of low-severity fire was throughout the forest.

11. OPTIONAL: To show the students how to proceed when they get their individual photo posters, project the handout. Go through it together using your real fire-scarred tree cookie. Refer to the key with answers for the real cookie provided in your trunk.

Assessment, Parts I and II: Telling a Tree’s Story

- Explain: Each student or team will examine a poster that shows a fire-scarred tree cookie and lists the dates of earliest and most recent wood and all fire scars. These specimens are taken from a study of fire scars on Jeffrey pines that was conducted on the east slope of the Sierra Nevada and published in a journal (Vaillant and Stephens, 2009).
- Explain: Follow the directions on **Handout M17-1:** Sketch the cookie, mark the location of each fire scar, calculate the intervals between fires, and complete the rest of the handout.
- Give a photo poster to each student or pair of students. Have them complete the handout. Circulate around the room to help.
- After all have finished the handout, ask students to report briefly, such as by asking for the shortest and longest fire intervals, the least and greatest numbers of fire scars. Discuss Questions 6-9.

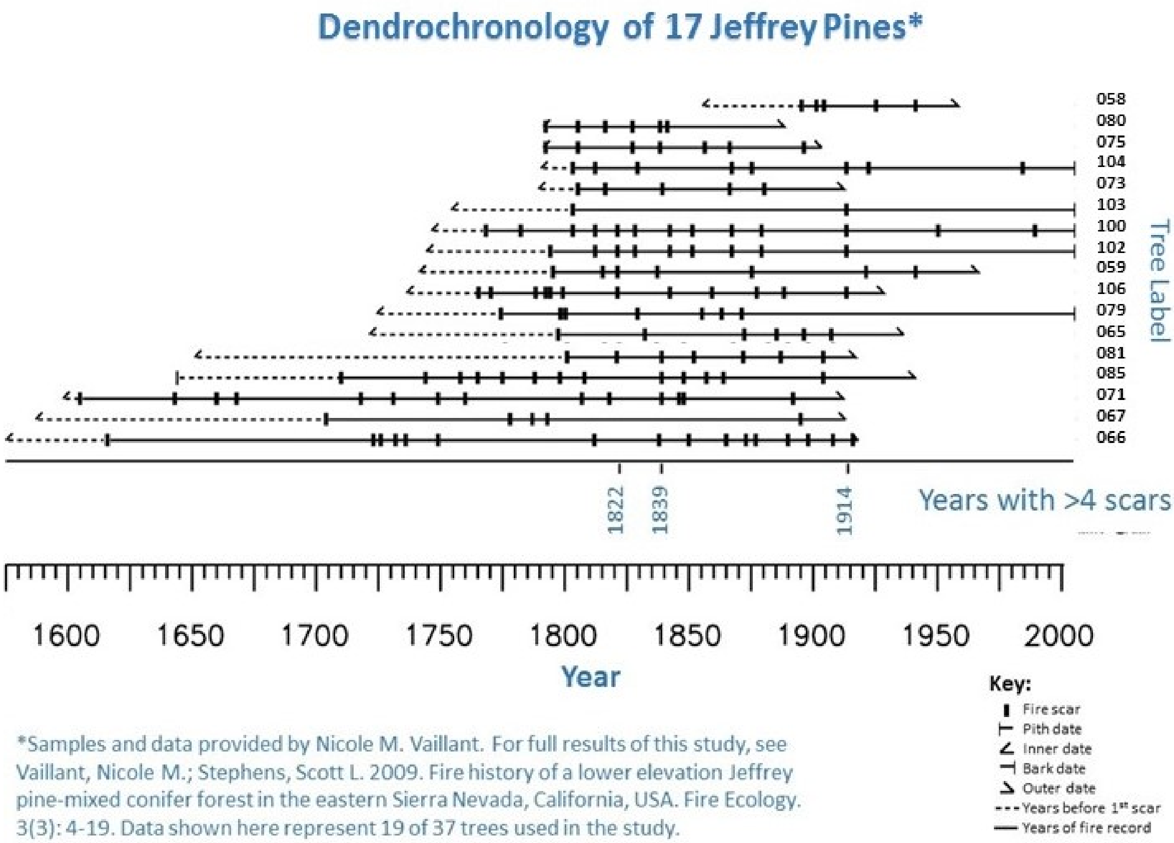
Procedure, Part III: Telling the Story of a Whole Forest

12. **Pooling data:** Draw a timeline on the bottom of the board that goes from 1550 (at left) to 2010 (at right), with 5-year increments.

13. Explain: We’ll pool our data to make a *stand history diagram.*

14. Have the students come up to the board with their handouts and sketches, one team at a time, <u>starting with the oldest tree and progressing to the youngest</u>.

15. Start at the bottom of the chart. For each tree cookie photo poster, have the team draw a line that starts with the earliest date and ends with the most recent date. Have them draw a short vertical bar across the line for each year when fire scarred the cookie. The class's chart should look sort of like this:



TAKE A PHOTO OF THE CLASS'S STAND HISTORY DIAGRAM TO USE IN THE NEXT ACTIVITY!

16. OPTIONAL: Display p. 9 from **VaillantStephens_2009.pdf** (the study that provided the photo posters and data). The class data are a subset of what is shown in the paper's stand history diagram, although the authors split out their data to show the 5 different forest stands that were sampled.

17. Summarize the information from the photo posters as a class.
    a) How many years were "fire years" – that is, years when low-severity fire scarred at least 1 tree? (94).
    b) How many fire intervals is that? (94-1=93)
    c) How many years elapsed between the earliest and final fire scars? Add 1 to get the full number of years in the period when low-severity fires occurred (from 1605 to 1990, inclusive: 386 years).
    d) What is the average number of years between low-severity fires? (386/93=4.2 years)

Assessment, Part III: Telling the Story of a Whole Forest

- Have students pair up and take 2 minutes to discuss: If you were living in montane forests of the Sierra Nevada 300 years ago, how many low-severity fires would have probably burned through your neighborhood in your lifetime? How would they have affected you?

- Come together as a class to discuss the answers and what they have learned about low-severity fire in the Sierra Nevada. Try to draw out the following:
  a) Trees can survive low-severity fires.
  b) Low-severity fires in this forest happened pretty often. A 16-year-old had probably seen 3-4 of them, though not always in the same place.
  c) Not every low-severity fire scars every tree in a forest. Perhaps fire spread is patchy rather than uniform. Perhaps some trees are more susceptible to scarring than others at any given time.
  d) The history of low-severity fire goes back hundreds of years.
  e) This forest has not seen many low-severity fires in the past century.

Evaluation:

Parts I-II, A Tree's Story	Complete	Incomplete
Handout Questions 1-5	All questions answered consistent with the *Cookie Book*.	Not all answered.
Handout Question #6	Answer is consistent with photo poster.	Answer is not consistent with photo poster.
Handout Question #7	Poor growth is likely to occur after fire if the fire killed many of the tree's needles or much of the cambium. Rapid growth after fire may be caused by decreased competition from other vegetation for moisture and nutrients or by an increase in nutrients from burned vegetation.	Did not indicate a relationship between fire and the availability of water and/or nutrients.
Handout Question #8	Decreases in fire activity can be caused by moist time periods and increases by dry time periods. Not many trees in the Sierra Nevada have fire scars dating after 1900 because successful programs excluding fire from forests and grasslands began in those years and also because livestock grazing reduced fine vegetation (fuels) such as grass and shrubs.	Did not provide rationale or relevant examples.

Handout Question #9	Answers to this question vary from place to place and from one plant community type to another. When low-severity fire is excluded from a forest for a long time, dense undergrowth and deep duff may develop. These conditions make fires very hazardous and likely to kill even large, old trees. A dense understory can also weaken large, old trees by competing for moisture and nutrients. Lack of fire may also reduce diversity in patches of different vegetation and ages across the landscape, increasing the potential for fires to spread across large areas when burning conditions are right.	Student did not use evidence from photo poster to support answer.
Handout graphic	Consistent with *Cookie Book* photo.	Not provided or not consistent with *Cookie Book* photo.
Part III, the Story of a Whole Forest	-Transferred results accurately from handout to stand history diagram on board. -Participated in discussion with imagination and valid points.	-Did not transfer results or transferred results inaccurately. -Did not participate in discussion relevant to the question.

Handout M17-1. A Tree's Story

Name: ___________________

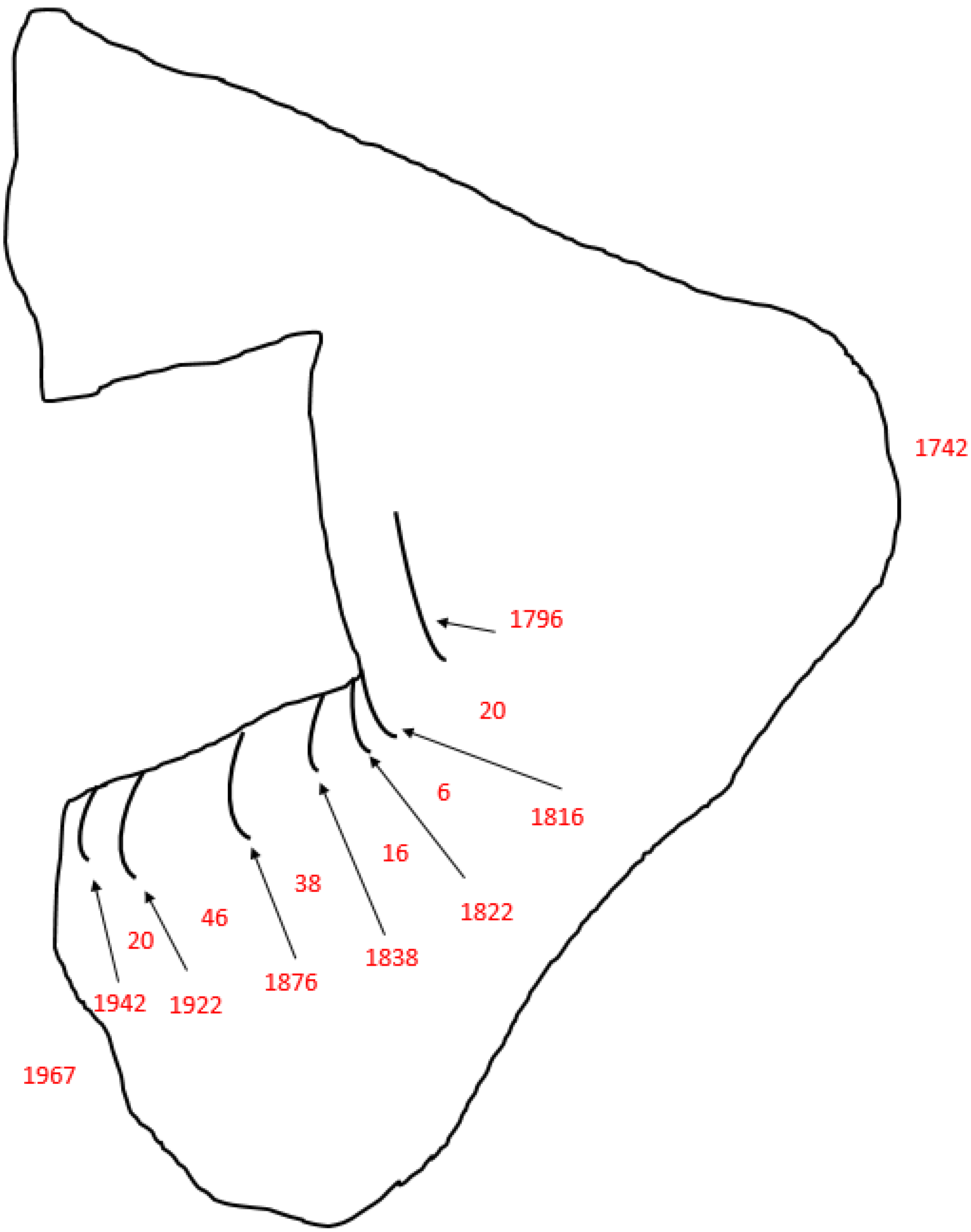
Species: ______________________ Cookie Number ________________

1. How many years of history does your tree cookie cover? _____________ years
2. On a separate page:
   - Sketch the outline of your tree cookie.
   - Label the sketch with the dates of the earliest and most recent growth rings.
   - Draw an arrow to each fire scar and label it with the date of the fire.
   - Calculate the number of years between each pair of fire scars. Write it in the space between each pair of arrows.
3. How many *low-severity fires* scarred your tree? ______________
4. How many *fire intervals* are recorded on your tree? ________
5. What is the average interval between fires? _________ years (If you only have 1 scar, go to the next step.)
6. Wide growth rings show years of fast tree growth, when moisture, sunlight, and nutrients were plentiful. Narrow rings show years of slow growth caused by drought, disease, injury, shading, or crowding by other trees. In what years did your cookie show fast growth? _____ In what years did it grow very slowly? ________
7. Were the years right after fire usually good or poor for growth? _____________________ What might be some reasons?
8. Did your tree record fewer fires after 1900 than before? _____ If so, what might be some reasons? (If your tree died before 1900, go to the next question.)
9. Could a tree be damaged by <u>lack</u> of low-severity fire? Explain why or why not.

Teacher's Key to Handout M17-1. A Tree's Story.
This is an example for Tree 59. For answers specific to all of the photo posters in your trunk, see the ***FireWorks Cookie Book – Low-severity Fire on the Sagehen Experimental Forest*** (in the trunk and also here).

Species: Jeffrey pine Cookie Number 59

1. How many years of history does your tree cookie cover? 1967-1742= 225 years +1 to account for both earliest & most recent rings = 226 years (also written on poster)
2. On a separate page:
   - Sketch the outline of your tree cookie.
   - Label the sketch with the dates of the earliest and most recent growth rings.
   - Draw an arrow to each fire scar and label it with the date of the fire.
   - Calculate the number of years between each pair of fire scars. Write it in the space between each pair of arrows.
3. How many *low-severity fires* scarred your tree? 7
4. How many *fire intervals* are recorded on your tree? 6
5. What is the average interval between fires? 24.3 years (If you only have 1 scar, go to the next step.)
6. Wide growth rings show years of fast tree growth, when moisture, sunlight, and nutrients were plentiful. Narrow rings show years of slow growth caused by drought, disease, injury, shading, or crowding by other trees. In what years approximately did your cookie show fast growth? Around 1942 to 1957 (the earliest 15 years that we can see)
   In what years did it grow very slowly? After the first fire, around 1796
7. Were the years right after fire usually good or poor for growth? Poor, this tree had very slow growth for most of its life
   What might be some reasons? This answer is in general, not specific to this tree. More or less competition, damage from loss of cambium and introduction of pathogens, short-term increases in nutrient availability
8. Did your tree record fewer fires after 1900 than before? Yes, 5 fires occurred before the 1900s and 2 fires occurred after. However, the tree's record is also longer before 1900 (1900-1796=104) than after (1942-1900=42). Fire was slightly more frequent (mean fire interval=20 years) before 1900 than after (mean fire interval=33 years). If so, what might be some reasons? (If your tree died before 1900, go to the next question.) Some trees in this poster collection show far fewer fires after 1900. This may be due to fire suppression, less American Indian burning, a wetter climate, or a combination of these factors.
9. Could a tree be damaged by lack of low-severity fire? Explain why or why not. Yes. Competition from other trees may increase, reducing sunlight, water, and nutrients available to the tree. Ladder fuels may increase likelihood of lethal fire.


1742
1796
20
1816
6
1822
16
1838
38
1876
46
1922
20
1942
1967

18. Fire History 2: History of Stand Replacing Fire

Lesson Overview: Students learn how to use *increment cores* from trees to discover the history of stand-replacing fire in a forest. They use what they have learned in both this activity and the previous one to depict how fire history influences the composition and structure of forest over a landscape.

Lesson Goals: Understand how to discover the history of stand-replacing disturbances in a forest. Understand that many forests have a history of both low-severity and stand replacing fire. Be able to depict a forest based on a description of its fire history.

Subjects: Reading, Writing, Speaking and Listening, Math, Science

Duration: 1-2 30-minute sessions

Group size: Whole class, working singly or in pairs

Setting: Classroom

New FireWorks vocabulary: *cohort, dendrochronology, fire regime, increment core, pith*

Objectives:

- Students can depict the structure and appearance of forests that have experienced low-severity and stand-replacing fire.

Standards:		**6th**	**7th**	**8th**
CCSS	Speaking and Listening	1,2,4,6	1,2,4,6	1,2,4,6
	Writing	1,4,10	1,4,10	1,4,10
	Writing: Science and Technology	3,4,7,9,10		
NGSS	Structure, Function, and Information Processing	LS1.A		
	Natural Selection and Adaptation	LS4.C		
	History of Earth	ESS2.C		
EEEGL	Strand 1	A,B,C,E,F,G		
	Strand 2.2	A		

Teacher Background: In **Activity M17. Fire History 1: Long Stories Told By Old Trees**, students learned how low-severity surface fires leave scars on trees. They used fire scars to describe the history of low-severity fire for mixed-conifer and Jeffrey pine forests in the Sierra Nevada. Numerous studies have documented an extensive history of low-severity fire in the Sierra

Nevada's montane forests[1], while large, severe, *stand-replacing fires* have not been considered a major influence on California mixed conifer, Jeffrey pine, or even red fir forests. However, we know that some kinds of forest in the Sierra Nevada thrive after stand-replacing fire and may even need it to persist. Baker cypress is one such forest type.

How can we learn about fire history when there are no fire-scarred trees? We can analyze the ages of trees in the stand; if most of them established within a short time, we call that a *cohort* – and cohorts usually establish after some kind of severe disturbance, such as fire.

To analyze the tree ages in a stand and look for cohorts, dendrochronologists use *increment cores* taken from living trees and dead wood. They figure out the approximate year when each tree was established – that is, when it germinated and started to grow. If most of the trees originated within 10 to 15 years of each other, they are considered a cohort. To figure out what disturbance allowed so many trees to establish in such a short time, scientists look for other evidence: Cut stumps would suggest logging; the presence of large numbers of old logs would suggest windthrow; the presence of scorched wood or charcoal in the soil would suggest stand-replacing fire.

In general, trees add one growth ring each year; however, tree growth is a little trickier than it looks. Sometimes a tree produces more than one growth ring during a single year; sometimes, especially in times of severe stress, it produces a ring only part-way around – or no ring at all. To determine the exact dates of rings on a core, dendrochronologists use a process called *cross dating.* They compare the rings on a core with descriptions of ring widths from a *master chronology* for the region. The master chronology is based on dozens to hundreds of cores. The scientists find especially narrow rings or groups of rings with a unique pattern of growth. Once they assign dates to these *marker years,* they can assign dates to the whole core. The year of the *pith* (the center of the tree, the oldest wood in the core) is close to the year when the tree germinated and started to grow. If the core was taken very close to the ground, it could even be the tree's first year of growth. More likely, the tree was a few years old by the time it reached the height where it was cored.

Historically, the forests of the Sierra Nevada experienced stand-replacing fires in relatively small areas. A few species seem well adapted to stand-replacing fire, such as the McNab cypress[2] and the Baker cypress[3], although their fire history has not been studied extensively. We do not have

[1]Here are three articles that document a history of low-severity fire in the Sierra Nevada:
Moody, Tadashi J.; Fites-Kaufman, JoAnn; Stephens, Scott L. 2006. Fire history and climate influences from forests in the northern Sierra Nevada, USA. Fire Ecology. 2(1): 115-141.
Scholl, Andrew E.; Taylor, Alan H. 2010. Fire regimes, forest change, and self-organization in an old-growth mixed-conifer forest, Yosemite National Park, USA. Ecological Applications. 20(2): 362-380.
Vaillant, Nicole M.; Stephens, Scott L. 2009. Fire history of a lower elevation Jeffrey pine-mixed conifer forest in the eastern Sierra Nevada, California, USA. Fire Ecology. 5(3): 4-19.
[2] Mallek, Chris R. 2009. Fire history, stand origins, and the persistence of McNab cypress, northern California, USA. Fire Ecology. 5(3): 100-119.
[3] Frame, Christine. 2011. Saving the cypress: Restoring fire to rare, at-risk species. Boise, ID: Fire Science Brief. 126. 6 p. See also Rentz. Erin; Merriam, Kyle. 2011. Restoration and management of Baker Cypress in northern

increment cores from these species for this activity, so instead we use photos of cores collected in a forest in central Oregon[4] as surrogates. Students will determine the earliest date on each core, draw a stand history diagram, and then describe the history of stand-replacing fire for the stand.

This lesson ends with students reading a qualitative description of the overall historical pattern of fires across the landscape, given in **Handout M18-1. How Fire Shaped the Landscape.** If desired, see **Skinner&Chang_1996_fireRegimes.pdf** for the full article).

Dendrochronology is used for dozens of applications, including studies of climate change, archaeology, and even dating the age of old musical instruments! Lots of information about dendrochronology is available at http://ltrr.arizona.edu/about/treerings. If you would like to delve into this field and teach dendrochronology in your classroom, look for materials at http://ltrr.arizona.edu/educators.

Materials and preparation:

- Either display (or keep a photo ready to project) of the stand history diagram that the class constructed in **Activity M17. Fire History 1: Long Stories Told By Old Trees.** If you can't find it, you can use the stand history diagram from Step 15 of that activity, "Dendrochronology of 17 Jeffrey Pines."
- Make 1 copy/student: **Handout M18-1. How Fire Shaped the Landscape**
- Open and prepare to present the National Park Service's slide show on dendrochronology at http://www.nps.gov/webrangers/activities/dendrochronology/.
- Find in the trunk (or print your own):
  - ***M18_DataFromSodaStraw&DotDiagr2.pptx*** poster. Display it in your classroom.
  - Set of photos of increment cores (each is a thin strip of laminated paper, 20-40 cm long, with a tree identification number written at the end). Available: ***IncrementCorePhotos.pptx***

Procedure:

1. Explain: You already know how to use fire scars and tree growth rings to learn about a forest's history of low-severity fires. That is really important because it is the most common kind of fire that occurred historically in Sierra Nevada forests. However, it is not the whole story. In this activity, we'll use *increment cores* to learn about a forest's history of stand-

California and southern Oregon. In: Willoughby, J. W.; Orr, B. K.; Schierenbeck, K. A.; Jensen, N.; eds. Proceedings of the CNPS Conservation Conference: Strategies and Solutions; 2009 January 17-19. Sacramento, CA: California Native Plant Society: 282-289.

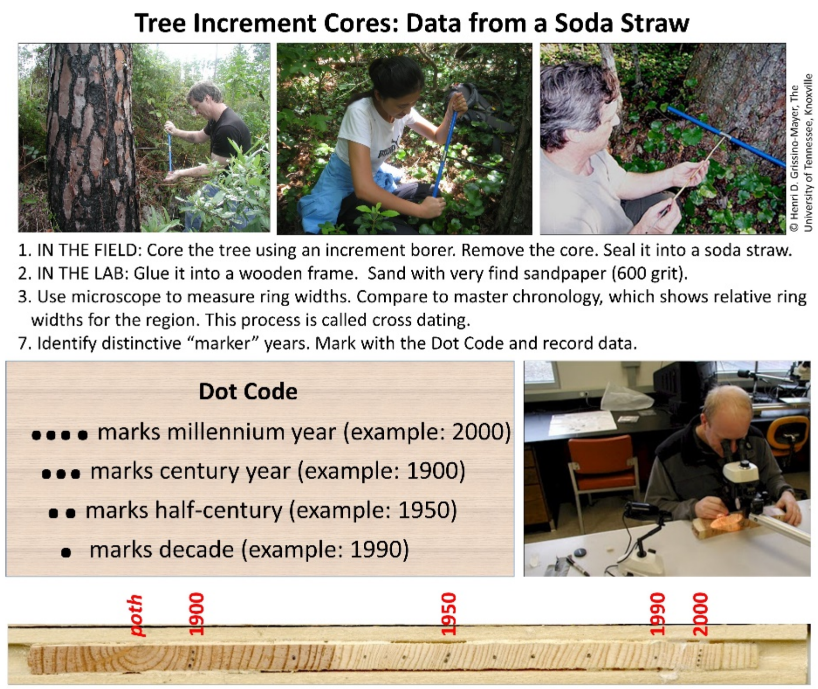
[4] Heyerdahl, Emily K.; Loehman, Rachel A.; Falk, Donald A. 2014. Mixed-severity fire in lodgepole pine dominated forests: are historical regimes sustainable on Oregon's Pumice Plateau, USA? Canadian Journal of Forestry. 44(6): 593-603.

replacing fires. In past centuries, these were usually small in the Sierra Nevada, but they were very important for providing diverse habitat – especially for unique species like the Baker cypress. Stand-replacing fires have become much more common in the Sierra Nevada during the past few decades.

2. Explain: From increment cores, we can learn the approximate year when a tree was established. How would that relate to stand-replacing fire? This is a food-for-thought question. If they don't come up with an answer now, let it rest. They should see it clearly when they construct the stand history diagram. Basically, here is the concept: If lots of trees established all at once, it could be because the previous forest was mostly killed by fire and the site was opened up for germination of fast-growing, sun-loving species.

3. Go through the National Park Service's slides on dendrochronology, http://www.nps.gov/webrangers/activities/dendrochronology/.

4. Hand out the photos of increment cores provided in the trunk. Explain: These cores were actually collected in central Oregon, but we are going to use them to represent the kind of information we might get from a mature stand of Baker cypresses that established after fire. Dendrochronologists have already dated each of these cores. This process is a little more complex than just counting rings, so the scientists have marked the cores to help you figure out their ages.



5. Review the dendrochronology procedures in the poster ***M18_DataFromSodaStraw&DotDiagr2.pptx***, and keep the poster on display so students can refer to the Dot Code at the bottom. **Note:** The poster uses a few terms –*cross dating, increment borer,* and *master chronology* – that students do NOT need to know in order to complete this activity. Explain the terms as you go over the poster, but you don't need to emphasize them.

6. Have each student or team determine for their core and write on a slip of paper: (You can check students' data against the study results, which are shown in **Table M18-1. Tree ages from one cohort in one stand** below):

    a) the earliest date on the core (the year of the *pith*)

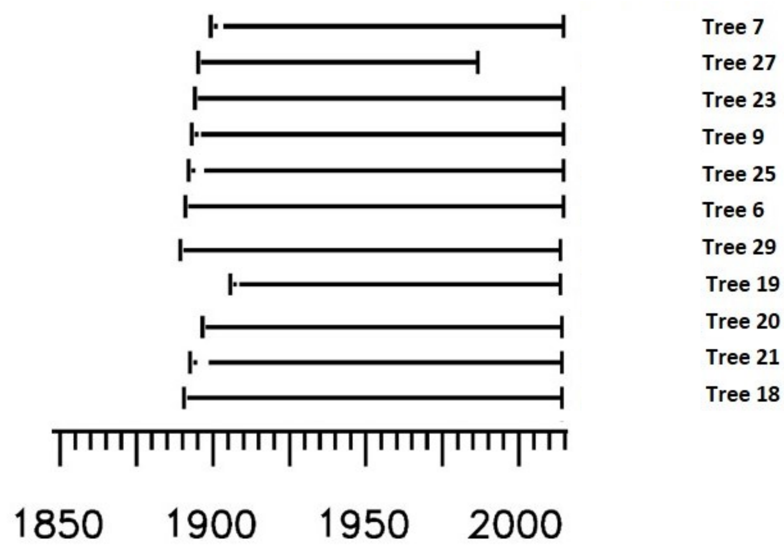
b) a series of years when the tree had its best growth

c) a series of years when the tree had its poorest growth

d) the most recent date on the core

7. Draw a timeline along the bottom of the board, going from 1850 at left to 2010 on the right. Use increments of 5 years.

8. Starting with the oldest tree core at the bottom, have each student or team draw a line that shows the life span of their core. It should look a lot like the diagram at right – except in a slightly different order.



9. Explain: A group of living things that are all about the same age is called a *cohort.* You and your classmates constitute a cohort. Can you see evidence of a cohort in this stand history diagram? Almost all of the trees became established between 1880 and 1890. In dendrochronology, tree establishment within 10-15 years is considered a cohort because this much regeneration could all be due to a single disturbance.

10. Ask: Can you find any evidence of stand-replacing fire in the stand history diagram? The cohort could have become established after the overstory trees had been killed by fire, making excellent conditions for young pines to germinate and start growing.

11. What other disturbances might create a cohort of trees? Possibilities include a pine beetle epidemic, logging, a severe wind storm, etc.

12. Could you do anything to determine if fire was the cause? Look for nearby fire-scarred trees, charcoal in the soil, standing fire-killed snags and stumps, and fallen burned logs. Trees killed by severe fire often have an uneven, cupped surface where flames persisted a long time and burned part-way into the wood.

13. Give each student a copy of **Handout M18-1. How Fire Shaped the Landscape**. Have students read it.

14. Discuss the reading in class. Ask students to try to picture the landscape in their heads. Ask:

- What is an "extensive literature review"? It is an article based on information in other articles from the scientific literature. This particular literature review contains about 200 citations.

- What is “Euro-American settlement”? This is the time when European immigrants began to settle in California and change the landscape with large-scale agriculture, logging, and control of fires and floods. Historians give various dates to the beginning of Euro-American settlement. Many of them date it from the “gold rush” years of the mid-1800s.

- What was the general appearance/structure of the forest in historical times? The forest was mostly open – big, tall trees and not a lot of trees in the understory. But there was a lot of variety. Since the authors say there was some stand-replacing fire, there must have been some patches with cohorts of trees.

- What is a “relatively fine” pattern? It means there are many patches, and they are fairly small. As you walked up a mountainside, you would come across patches that had burned recently and some that had not burned for quite a while. Most of the patches had burned in low-severity fire, so you would see multiple fire scars on the big trees. You would see a few patches with cohorts (trees all about the same size, whether small or large) that had burned in stand-replacing fires.

Assessment: Explain: Each student or team will create a depiction of the Sierra Nevada landscape that shows how the landscape looked in historical times (prior to Euro-American settlement).

- You will include the 2 forest histories we have just studied – a pattern of frequent low-severity fire in montane mixed-conifer forest and a pattern of infrequent stand-replacing fire in Baker cypress stands.
- You can refer to the stand history diagram completed in **Activity 17** and the one completed in this activity (shown above).
- You can use any art form - drawing, painting, computer graphics (possibly animated), a model forest in a sand box or clay substrate, etc.
- Your depiction should contain at least 20 mature trees of at least 3 different species (especially for the forest with frequent low-severity fire). It should also contain at least some young trees and some understory plants.

Evaluation: For full credit, students' depictions should include these features.

Fire regime	Frequent low-severity fire (as illustrated in Activity M-17)	Less frequent high-severity fire (as illustrated in Activity M-18)
Overstory trees	Variety of sizes, including very large Many fire scars on trunks	Similar in size, none very large No fire scars on trunks
Tree species	Should contain either ponderosa pine or Jeffrey pine, plus other species	Should contain Baker cypress
Stand structure	Trees widely spaced	Trees close together
Understory trees	A few small trees	No small trees
Understory vegetation	Grass, wildflowers, and perhaps a patch or two of shrubs	Very sparse

Table M18-1. Tree ages from one cohort in one stand[1]

The table shows the species of each increment core. Students do not need to provide that information for this activity.

Species	Tree number	Earliest date
Lodgepole pine	6	1890
Lodgepole pine	7	1898
Lodgepole pine	9	1892
Ponderosa pine	18	1887
Ponderosa pine	19	1903
Ponderosa pine	20	1893
Ponderosa pine	21	1889
Lodgepole pine	23	1893
Lodgepole pine	25	1891
Lodgepole pine	27	1894
Lodgepole pine	29	1887

[1]Source: Heyerdahl, Emily K.; Loehman, Rachel A.; Falk, Donald A. 2014. Mixed-severity fire in lodgepole pine dominated forests: are historical regimes sustainable on Oregon's Pumice Plateau, USA? Canadian Journal of Forestry. 44(6): 593-603. Table includes only data from samples collected for stand age analysis. Cores that could not be scanned are not included.

Handout M18-1. How Fire Shaped the Landscape

The authors of an extensive literature review published in 1996[5] consulted more than 200 scientific articles to learn about historical fire regimes in the Sierra Nevada. They wrote that, before Euro-American settlement, most of the landscape burned fairly often, and most of the fires were of low severity. However, there were definitely patches that seldom burned, and there were definitely patches that burned with stand-replacement severity.

Photo by Ilana Abrahamson. Used with permission.

The authors described the Sierra Nevada landscape as having a "relatively fine" pattern. Much of the landscape contained large, old trees and had mostly an open structure with few trees in the understory. But the landscape was very diverse and also included dense patches of trees that had established after stand-replacing fires.

Photo by Brady Smith, USFS

USDA Forest Service photo provided by Ilana Abrahamson.

Photo by Kyle Merriam.

[5] Skinner, Carl N.; Chang, Chi-ru. 1996. Fire regimes, past and present. In: Status of the Sierra Nevada. Sierra Nevada Ecosystem Project: Final report to Congress. Volume 2: Assessments and scientific basis for management options. Wildland Resources Center Report No. 37. Davis, CA: University of California, Centers for Water and Wildland Resources: 1041-1069.

M19. Drama in the Forest: Fire and Succession, a Class Production

Lesson overview: Students prepare and produce two short plays, each depicting the role of fire, succession, and on-going changes in a forest community.

Goals: Increase understanding of change in ecosystems over time—caused by succession, fire, and other disturbances.

Objectives:

- Students will produce a drama that illustrates succession, the role of fire, and other processes that change forest communities.

Subjects: Science, Reading, Writing, Speaking and Listening, Social Studies, Arts

Duration: 1-2 class periods for student preparation, about 15 minutes for each of three presentations

Group size: large groups

Setting: Classroom

New FireWorks vocabulary: *disturbance*

ABOUT STUDENT PRESENTATIONS: All presentations from **Activity M11. Who Lives Here? Adopting a Plant, Animal, or Fungus** should be completed before you do this activity.

Standards:		6th	7th	8th
CCSS	Writing	3,4,6,7	3,4,6,7	3,4,6,7
	Reading: Informational Text	4,7,10	4,7,10	4,7,10
	Speaking and Listening	1,2,4	1,2,4	1,2,4
	Reading: Science and Technology	3,7,10		
	Writing: Science and Technology	2		
NGSS	Interdependent Relationships in Ecosystems	LS2.A, LS2.C, LS4.D		
	Matter and Energy Flow in Organisms and Ecosystems	LS1.C		
	Earth's Systems: Processes that Shape the Earth	ESS2.A		
	Growth, Development, and Reproduction of Organisms	LS1.B		
EEEGL	Strand 1	A,C,E,F,G		
	Strand 2.2	A,C,D		

Teacher Background: Forests change over time. One of the most dramatic forces of change in forests of Sierra Nevada is fire, but there are other *disturbances* too, such as wind storms, floods, landslides, and epidemics of insects and fungi. Change also occurs without disturbance in the process called *succession*.

After fire, more sunlight and water are available to understory plants, some soil nutrients have increased, and the soil is warmer on summer days. Plants that need sunny openings or high levels of nutrients thrive in the first years after fire, and some animals thrive on these plants. As years go by, shrubs begin to shade out the smaller plants, and then trees begin to shade out the shrubs. Plants that need sunny openings decline, and those that can grow and reproduce in shade take over. The animals that depend on them are present only in old forests.

This *FireWorks* activity asks students to work on two teams (one for each forest community). The teams use information in the *FireWorks Encyclopedia* to present a play showing the history of fire and succession in each community, from about 1700 to the present. Several of the characters in the plays occur in both communities, but they are depicted in only one community for this lesson.

If you want to link this activity to physical science, you can point out that an ecosystem is a huge reservoir of high-energy chemical bonds among carbon, oxygen, and hydrogen atoms. Trees and other plants add to the reservoir every day when they capture the sun's energy and store it in their tissues, but they can't keep the carbon to themselves. Fungi grab it from the plant tissues so they can grow and reproduce. Insects grab it from on leaves, needles, tree cambium, and dead tissues. Mammals and birds eat leaves, stems, seeds, and even tree bark. This is often referred to as a food web, but it can also be viewed as a pool of carbon moving about, taking one form after another as the energy originally stored by plants is mined and the atoms are recycled. Fire is a powerful, dramatic recycler.

Materials and Preparation:

- Fill out the Cast of Characters for each drama (**Handout M19-1: Casts of characters**), and print a copy for each drama production team. Students may represent the same character as they did in **Activity M11: Who Lives Here? Adopting a Plant, Animal, or Fungus**, or they may be a different character. If possible, have them use the props from Activity M11.
- Students can get the information they need for this drama from the *FireWorks Encyclopedia* (**FireWorks Encyclopedia_Older grades.pdf**). If they need additional information or if you want them to do additional research, many resources are available, including the introduction to this FireWorks curriculum and also the narrative for *The Storrie Fire Story* (Elementary curriculum: **E14_StoryTime/ TheStorrieFireStory.pdf**)*,* which depicts the history of fire and succession for Elementary-age students.

Procedure

1. Explain: Students will work in teams to present a drama that describes the history of two forest communities (lower and upper montane mixed-conifer forests in the Sierra Nevada)

from about 1700 to the present. Each team will produce a play about 15 minutes long that shows the relationships among different organisms, the role of fire, the pattern of succession after a typical fire, and how the community has changed in the past 100 years or so, either in the absence of fire or with a different kind of fire than occurred historically.

2. Have the students for each drama work together to figure out how to portray the history of their forest community. Even though some species occur in both communities, species are assigned to only one community for these plays.
3. Have students do additional research if necessary, plan their plays, and rehearse.

Assessment: Have students produce their plays for one another and, if possible, for another audience – perhaps a younger class or a parent group.

Evaluation	Full Credit	Partial Credit	Less than partial
Group Contribution	Student made many contributions during group planning. Student allowed other teammates to participate.	Student made few contributions during group planning but listened actively and was supportive of others.	Student did not make contributions during group planning or took over the planning and did not allow others to participate.
Individual Contribution	Student was well prepared for the presentation.	Student was prepared for the presentation.	Student was not prepared for the presentation.
Content	Information was accurate. Many facts were used.	Information was accurate but presented few facts.	Information was not accurate. No facts were used.

Handout M19-1: Casts of characters for two drama productions

Lower montane mixed conifer forest	Name
Ponderosa pine	
White fir	
California black oak	
Sugar pine	
Canyon live oak	
Douglas-fir	
Incense-cedar	
Deer brush	
Yellow star thistle	
Cheatgrass	
Webber's milkvetch	
Wavyleaf soap plant	
Mountain lion	
Dusky-footed woodrat	
Western gray squirrel	
Mule deer	
Bark beetles	
California spotted owl	
Northern goshawk	
Annosum root rot	
White pine blister rust	

Upper montane mixed conifer forest	Name
Jeffrey pine	
California red fir	
Sierra lodgepole pine	
Baker cypress	
Quaking aspen	
Mountain whitethorn	
Sticky whiteleaf manzanita	
Sierra gooseberry	
Ross's sedge	
Mariposa lily	
Bracken fern	
American black bear	
Fisher	
Deer mouse	
Mountain yellow-legged frog	
Black backed woodpecker	
Fox sparrow	
Western wood-pewee	
Black fire beetle	

Produce a play that shows the audience about your forest community, how fire changes it, and how it has changed since about the year 1700.

1. Get together with all of the students representing species in your forest community, listed above.
2. Learn about *succession* by discussing the needs of cast members, which they learned from their pages in the *FireWorks Encyclopedia*.
3. Select one person to narrate the presentation. That person will portray his or her character in the play too.
4. Prepare your play. Plan for about 15 minutes. You must show:
    - How different organisms interact (who needs whom for food or shelter)
    - One fire or more. You must show the kind of fire that was typical in this kind of forest during the 1700s and 1800s.
    - How the forest community changes right after fire and then as many more years go by.
    - How your forest community has changed in the past 100 years or so, either after a fire or because it needs a fire.
5. Perform your play for your class or another audience.

Unit VII. People in Fire's Homeland

20. Homes in the Forest: An Introduction to Firewise Practices

Overview: In this activity the class uses their knowledge of vegetation, fuels, and fire behavior to develop guidelines for protecting homes from wildland fire. Students assess the safety of photos of wildland homes and make recommendations for home owners.

Goal: To increase students skill in applying their knowledge of wildland fire to figuring out how to protect homes from fire.

Subjects: Science, Reading, Writing, Speaking and Listening, Health

Duration: One class period

Group size: Whole class/Partners

Setting: Classroom

New FireWorks vocabulary: *dilemma, hazard*

Objective:

- Students will develop guidelines for protecting homes from wildfire.
- Students can assess the hazards on and around homes in wildland settings.
- Students can recommend steps to reduce the risk of wildfire damage to homes.

Standards:		6th	7th	8th
Common Core ELA	Writing	1,4	1,4	1,4
	Speaking and Listening	1,2,4	1,2,4	1,2,4
	Science and Technology	7	7	7
NGSS	Human Impacts	ESS3.B, ESS3.C		
	Engineering Designs	ETS1.A, ETS1.B		
EEEGL	Strand 1	A,C,E,F,G		

Teacher background:
This activity challenges students to apply their knowledge about fire science to a real-world problem. Please note: This activity is no substitute for a thorough assessment of a home's protection from wildland fire. Materials for a thorough assessment are available from Firewise (http://www.firewise.org/wildfire-preparedness/teaching-tools/photo-library.aspx), a product of the National Fire Protection Association. All of the photos in this activity are from the Firewise website.

Here are the main Firewise principles and associated fire behavior concepts used in this activity:

- Are there any ways that a surface fire could spread from the edge of the forest right up to the home? (Surface fires need continuous fuels and spread especially well in dead, dry fuels. If there is a break in the continuity of surface fuels, a surface fire will stop.)

- Are there any places where an ember blown on the wind could land on or under something burnable and then start the home on fire? (Fires need fuels… Heat rises, so a smoldering ember under a deck or eave is dangerous.)
- Are there ladder fuels at the bases of trees near the house? (Heat rises… embers can fly from a burning tree crown)
- Is the access road wide enough and good enough for a fire engine to get to the house? (This is not likely to emerge from their study of fire science, but it is worth bringing out in discussion.)

Materials and Preparation

- Download and project PowerPoint ***M20-1_FirewiseHomes.pptx***, which has 4 photos. OPTIONAL: If you want to go through 12 additional photos with the class, download PowerPoint ***M20-2_MoreFirewiseHomes.pptx***.
- Make copies of **Handout M20-1: Making the rules and using them**, for <u>half of the class,</u> and make copies of **Handout M20-2: Making the rules and using them**, for the other half.

Procedure

1. Write on the left side of the board: "Ecosystems of the Sierra Nevada need wildland fire." Write on the right side: "Wildland fire can hurt people and destroy homes."
2. Ask: If you think the statement on the left is true (point to it!), raise your hand. Regardless of how many students respond, have some discussion. Ask for specific examples of organisms that need fire.
3. Ask: If you think the statement on the right is true, stand up. More discussion, if necessary.
4. Explain: These two things may both be true, but they also create a problem about what to do with fire. When we want 2 things that seem mutually exclusive, we call it a *dilemma.* Do we want fire or not? There are no easy solutions to this dilemma. What do you suggest? Discussion. Have students explain why various approaches might work – both in wildland management and in the care of private property and homes. Ask them to explain their reasoning based on their understanding of fire and fuels.
5. On the board, make a list with 2 columns: "Good job!" and "Needs work:" Explain: We'll look at photos of a few homes in wildland settings. For each photo, we'll list things that the home owner has done "right" to prevent the house from burning under "Good job!" and we'll list things that the home owner should still work on under "Needs work."
6. Go through PowerPoint ***M20-1_FirewiseHomes.pptx*.** With each slide, ask students to comment on features that show a "Good job!" and others that show "Needs work." Direct discussion with questions like these, and have the students explain their reasoning:

- Are there any ways that a surface fire could spread from the edge of the forest right up to the home? Why does it matter? (Surface fires need continuous fuels and spread especially well in dead, dry fuels.)
- Are there any places where an ember blown on the wind could land on or under something burnable and then start the home on fire? Why does it matter? (Fires need fuels… heat rises, so a smoldering ember under a deck or eave is dangerous.)
- Are there ladder fuels at the base of trees near the house? Why does it matter? (Heat rises… embers can fly from a burning tree crown)
- Do you see other fire *hazards* on the house or around it?
- Do you think the road is wide enough and good enough for a fire engine to get to the house? (Not likely to emerge from their study of fire science, but worth bringing out in discussion)

Slides and notes from *M20-1_FirewiseHomes.pptx*

Slide 1

Slide 2

Good job! -- Screened in porch is good, screening under the deck might be good to keep embers out if it was metal screening (although this should not be done with wooden lattice. Also some experts now recommend NOT doing this because the screening can trap embers), wide driveway is good, green grass is good.
Needs work: Clean the roof, get the duff out from base of trees, remove some trees from back of house, make sure area under steps is free of burnables.

Slide 3

Good job! Roof looks clean, there's little vegetation next to house, only a little surface fuels, there are no trees overhanging the house.
Needs work: Replace wood shake roof, rake needles from under trees.

Slide 4

Good job! House has a clean roof, there's little vegetation next to house, there are no trees overhanging house, there's a green lawn.
Needs work: Water the lawn a little more. Could remove some of the trees behind the house.

Slide 5

Good job! House has a clean roof and a green lawn, there's no vegetation close to house, house has shingle roof
Needs work: Get rid of the wood latticework below deck. Make sure there's no flammable stuff under there. Replace bark chips below deck with rocks.

7. If you want to evaluate more photos, go through PowerPoint ***M20-2_MoreFirewiseHomes*****.pptx**. The slides and notes are included at the end of this activity.

Assessment:
Have each student a complete either Handout **M20-1. Making the rules and using them** or **Handout M20-2. Making the rules and using them.**
Then have them team up with someone who completed the other handout, trade handouts, and review each other's rules (Question 1). Then have them and take on the role of a wildland fire safety inspector—re-inspecting the house and neighborhood, perhaps fine-tuning the other student's recommendations for improvement, and recommending further improvements if necessary.

Evaluation:	Complete	Incomplete
Question #1: The five rules could include any of the	The five rules could include any of these, plus others: -Keep the roof clean.	Student did not list five rules or listed incorrect/irrational

following.	-Make sure the roofing material is not flammable. -Maintain a strip of un-burnable material between the vegetation and the house. If shrubs are close to the house, make them short and far apart. -If trees are near the house, get rid of low branches. -Keep the lawn green. -Keep it mowed. -Keep junk from accumulating under the deck, steps, etc. – or leaning against the foundation. -Make sure the road is wide enough for a fire engine to get in while people are getting out. -Make sure there's a place big enough for it to turn around.		rules.
Question #2a: Good Job!	**Handout M20-1** -Clean roof -Woods near house are open. There are some barriers to keep embers from under deck and stairs.	**Handout M20-2** -Metal roof -Not many ladder fuels in front of house.	Student did not write about "good job" items that were relevant to their photograph. or correct.
Question #2b: Needs Work.	-Put better barriers under stairs and deck -Mow and water the grass around the house	-Put barriers around porch -Clean up logs around house -Trees are close to house. -Thin them out or at least prune the low branches (especially trees behind house).	Student did not write about "needs work" items that were relevant to their photograph.
Question #2c: Why?	-Keep embers from under wooden parts of the house. -Reduce fuels next to the house. -Keep them moist so they won't ignite easily.	-Keep embers from under wood parts of house -Reduce fuels around the house.	Student did not write a rational response.

Question #3a/#3b	#3a: Establish some areas that have little or no fuel, where tree crowns do not touch. #3b: Roads may not be wide enough or straight enough to maneuver an engine safely. It may be hard to find a specific address. Is there any place in this view where an engine could turn around? Are there blind corners where an engine going in might run into residents coming out?	

Handout M20-1. Making the rules and using them

Name: _______________

1. Use the "Good Job"/"Needs Work" list on the board to write five rules for improving a home's chances of surviving a wildland fire. Write the rules so they sound like orders, such as "Do this," "Do not do that." This is called the "imperative voice."
   a. ____
   b. ____
   c. ____
   d. ____
   e. ____

2. Use your five rules to evaluate the house in this photo.
   a. Good Job:
   b. Needs work:
   c. Why will the needed work improve the home's chances of surviving a wildland fire?

3. This photo shows a neighborhood in wildland setting.
   a. List one change that would reduce the likelihood that a fire would spread through the whole neighborhood:
   b. List one problem that a fire engine crew might have in trying to protect these homes:

Handout M20-2: Making the rules and using them

Name: ________________

1. Use the "Good Job"/"Needs Work" list on the board to write five rules for improving a home's chances of surviving a wildland fire. Write the rules so they sound like orders, such as "Do this," "Do not do that." This is called the "imperative voice."
   a. ____
   b. ____
   c. ____
   d. ____
   e. ____

2. Use your five rules to evaluate the house in this photo.
   a. Good Job:
   b. Needs work:
   c. Why will the needed work improve the home's chances of surviving a wildland fire?

3. This photo shows a neighborhood in a wildland setting.
   a. List one change that would reduce the likelihood that a fire would spread through the whole neighborhood:
   b. List one problem that a fire engine crew might have in trying to protect these homes:

Slides and notes for PowerPoint *M20-2 More Firewise homes.pptx*

Slide 1

Slide 2

Good job! Asphalt shingles – nonflammable.
Needs work: Clean the roof! Prune the limbs of trees that hang over the roof.

Slide 3

Good job! It's difficult to see positives from this distance and at this angle.
Needs work: Clear out shrubs and trees close to the house! Make sure there's a fuel separation between house and vegetation – rock or green lawn.

Slide 4

Good job! Asphalt shingles – nonflammable.
Needs work: Clean the roof! Trees seem to be hanging over the house, and limbs surround the chimney. Clear the branches away.

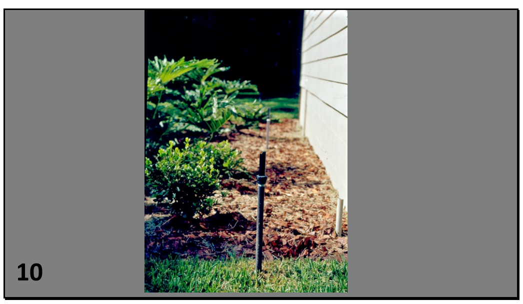
Slide 5

Good job! Trees in the area around the house have been thinned. The house looks free of clutter such as wood piles. The roof is clean.
Needs work: Get rid of logging sash. Prune lower branches from trees. Now that the area close to the house has been opened up, don't let it get brushy or dry out. Establish and maintain green lawn.

Slide 6

Good job! Clever the way rocks have been used to landscape around the foundation It looks like there's green lawn on the other side of the sidewalk It looks like trees in the background are spaced far apart**.**
Needs work: Can't think of anything other than maintenance.

Slide 7



Good job! It looks like there's some green lawn in the foreground.
Needs work: Are those bark chips next to the foundation? That's not a good idea. Keep the landscaping shrubs watered and moist.

Slide 8

Good job! The landscaping here obviously protected the home from a severe fire. The shrubs in the margin between forest and house are dead, but the rocks under them and the green lawn kept the fire from reaching the house. It looks like the roof is asphalt shingle (fire resistant). It is likely that the home owner keeps the outside of the house clear of debris that could ignite from firebrands.
Needs work: Hard to find anything to suggest.

Slide 9

Good job! Rock foundation for deck is a good idea. The forest is very open around the house. The house is built on a flat spot rather than on the hillside. It looks like there's a green lawn around the house.

Needs work: There seems to be a lot of vegetation around the deck. Reduce it or make sure it's plants that are difficult to ignite.

21. Revisiting Wildland Fire in the Sierra Nevada

Use this activity only if you used Activity M01, "Visiting Wildland Fire in the Sierra Nevada."

Subjects: Science, Writing, Speaking and Listening, Arts
Duration: one half-hour session
Group size: Whole class
Setting: Indoors
New FireWorks vocabulary: *fire manager*

Lesson overview: Students return to the presentation that they viewed in **Activity M01**, at the start of their study of wildland fire (***E01_M01_VisitingWildlandFire.pptx***). This time, they narrate the presentation themselves. Then they compare and contrast their current feelings about wildland fire with their earlier ones. Finally, they assess the difficulty of a fire manager's job.

Goals: Reinforce students' knowledge about wildland fire behavior, effects, and management. Demonstrate to students how much they have learned. Demonstrate that learning can affect feelings, and that feelings about a complex issue can change over time.

Objectives: Given a series of photos in a presentation…

- Students can narrate the presentation, describing different kinds of fire behavior and relationships between fire and ecosystems.
- Students can articulate and compare/contrast their feelings about wildland fire.
- Students can describe some of the challenges facing wildland fire managers and assess the difficulty of the job.

Standards:		6th	7th	8th
Common Core ELA	Writing	1,3,10	1,3,10	1,3,10
	Speaking and Listening	1,4,6	1,4,6	1,4,6
	Science and Technology	8	8	8
NGSS	Interdependent Relationships in Ecosystems	LS2.A,LS2.C,LS4.D		
	Human Impacts	ESS3.B,C		
	Weather and Climate	ESS2.C		
	Matter and Energy in Organisms and Ecosystems	LS2.C,B		
	Natural Selection and Adaptation	LS4.C		
	History of Earth	ESS2.A		
EEEGL	Strand 1	A,C,E,F,G		

Materials and preparation:

- Find the flipchart with questions that students asked about fire in **Activity M01. Visiting Wildland Fire in the Sierra Nevada**. Post it in the classroom.
- Find each student's earlier copy of **Handout M01-1**
- Make 1 copy/student of **Handout M21-1: Final Fire Drawings**
- Provide computer access for students (1 per every 2-3 students), and download ***E01_M01_VisitingWildlandFire.pptx*** on each computer, in "slide show" mode. If you don't have access to multiple computers, you can do this activity with the full class, rather than in small groups.

Procedure:

1. Group the students into teams of 2-3, where each team has a computer with ***E01_M01_VisitingWildlandFire.pptx*** loaded, ready to go in "slide show" mode (students should not look at the notes).
2. Give each student a copy of **Handout M21-1: Final Fire Drawings**.
3. Explain: You will work in teams to view the same presentation that you saw when we first began studying wildland fire. As you go through the slides:
   - Stop at each slide and discuss what it shows. You can explain the slides now because you have learned about everything that is shown here.
   - At slides 1, 8, 14, and 21, stop to draw the fire behavior and label it with the correct term.
   - Try to answer the questions on the flipchart (posted in the classroom). These came up at the start of our fire study. If we can't answer them, we'll talk about ways to get the answers.
   - When you finish the presentation, answer the questions at the bottom of the handout.
4. After the small group activity, go through the slideshow with the class. (Slides and narrative from **Activity M01** are shown below.) Ask a different group of students to explain each slide.
5. Ask for answers to the questions on the flipchart. If you don't have answers, discuss how you might get them (from further research? by asking a fire management professional?)
6. Ask/discuss: Now that you know a lot about wildland fire, what do you think a fire manager's job is like?

Assessment:

1. Return students' copies of **Handout M01-1: Fire Drawings**.
2. Explain: Read the "fire feelings" that you wrote when we began our study of wildland fire – the answer to Question 3 on the old handout. Then write a paragraph in which you compare and contrast your current feelings with your initial feelings. Give at least three specific examples of how your feelings of wildland fire have or have not changed. Explain why.
3. Write a paragraph to answer this question: How difficult is the job of managing wildland fire? Explain by giving at least 3 specific examples of things a fire manager has to do.

Evaluation:	Full Credit	Partial Credit	Less than Partial Credit
Small Group Discussion	-Student actively and frequently participated and listened during discussion. -Student gave others a chance to speak.	-Student gave a few contributions to the discussion. -Student was actively listening.	-Student did not contribute. -Student was not listening or was distracting others.
Class Discussion	-Student contributed at least once during the large group discussion. -Student was actively listening.	-Student did not contribute to large group discussion but was actively listening.	-Student did not contribute and was not listening or was distracting others.
Writing Assignment - feelings	-Student wrote a complete paragraph that clearly compared/ contrasted feelings. -Student provided 3 examples.	-Student wrote an incomplete paragraph that compared/ contrasted feelings. -Students provided 2 examples.	-Student wrote a poorly structured paragraph. -Student provided 0-1 example.
Writing Assignment – difficulty of fire management	-Student wrote a complete paragraph that answered the question. -Student provided 3 valid examples.	-Student wrote an incomplete paragraph or did not answer the question. -Students provided 2 valid examples.	-Student wrote a poorly structured paragraph or did not answer the question. -Student provided 0-1 valid example.

Slides and Narrative for *E01_M01_VisitingWildlandFire.pptx*

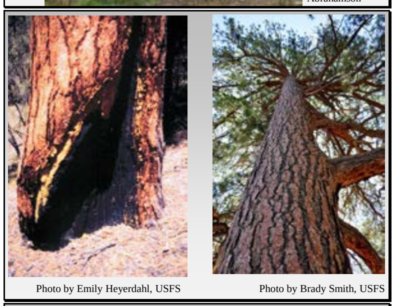
Slide 1

Here is a fire burning in a forest of the Sierra Nevada.

Slide 2

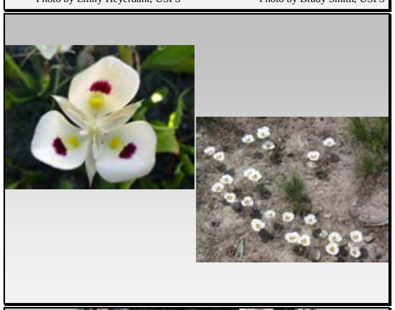
This is what the land looks like after that kind of fire.

Slide 3



Here are some plants that live in the forest after fire:
… A ponderosa pine tree that has survived many fires

Slide 4



… Mariposa lily, a wildflower that survives fire and then grows really well.

Slide 5

… A California black oak that sprouts after fire.

Slide 6

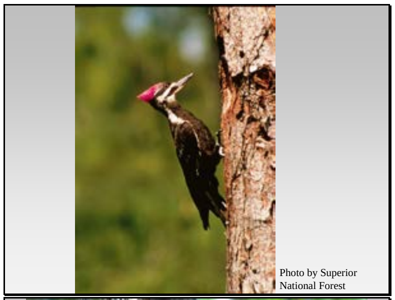


Photo by Superior National Forest

Here are some animals that live in the forest after fire:
… Pileated woodpecker, which loves big, old trees that have survived fires long ago.

Slide 7

Photo by Matt Vander Haegan

… Western gray squirrels that eat the seeds of trees that have survived the fire.

Slide 8

Photo by Michael Yager

Here is another kind of fire in the Sierra Nevada.

Slide 9

Photo by Michael Yager

This is what the land looks like after that kind of fire.

Slide 10

Photo by Ilana Abrahamson

Or this.

Slide 11

Here are some plants and animals that thrive after that kind of fire:
… A beetle with heat sensors, so it can find fires and lay its eggs in just-burned trees.

Slide 12

… A black-backed woodpecker, which arrives soon after the fire to eat the beetles.

Slide 13

… Deer brush, whose seeds germinate after fire cracks open its hard seedcoats.

Slide 14

Here is another kind of fire in the Sierra Nevada.

This is a mixture of the two kinds of fire you've already observed. Many of those plants and animals can live here after fire.

Slide 15

Fire behavior and fire effects vary with topography, weather, and vegetation. Here are examples of fire behavior fires in the Sierra Nevada.

Slide 16

Slide 17

Slide 18

Slide 19

Slide 20

Slide 21

Fires in our forests can burn for a long time after the flames have passed. They may burn in tree trunks, roots, or in the soil itself.

Here is what a fire may look like after most of the flames have moved on (left photo). *Observe and sketch it (D).*

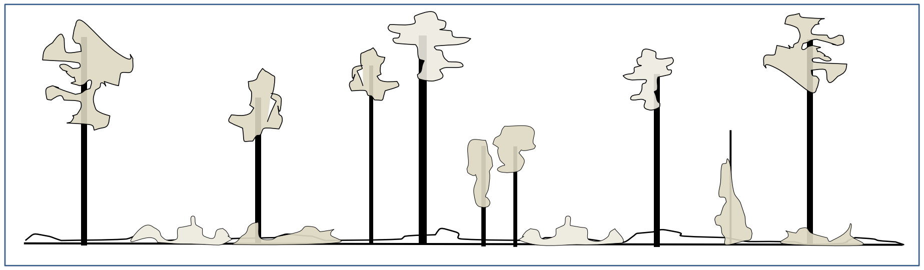
Wildland fires cause changes that last a long time, sometimes for hundreds of years. We'll learn more about all kinds of fire in the activities to come.

Handout M21-1: Final Fire Drawings.

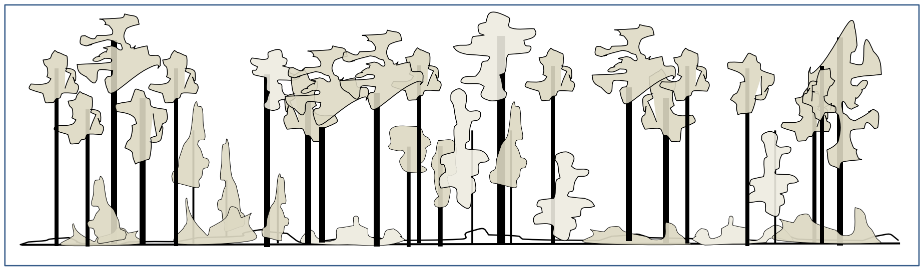
Name ______________________________

1. Color each sketch to show what part of the forest is burning (for example, soil, surface plants, or tree tops). Label the sketch with the kind of fire shown.

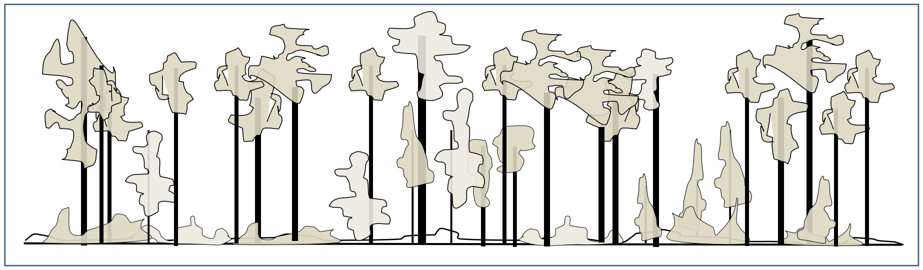
A. Slide 1. Kind of fire: __________________________



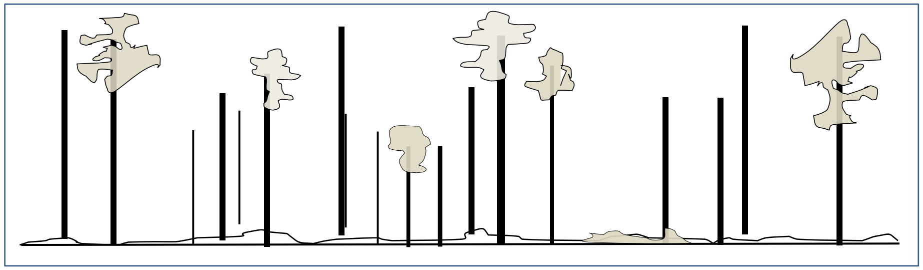
C. Slide 14. Kind of fire: ____________________________



B. Slide 8. Kind of fire: ____________________________



D. Slide 21. Kind of fire: ____________________________



2. Write a paragraph in which you compare and contrast your current feelings with your initial feelings (from Handout M01-1). Give at least three specific examples of how your feelings of wildland fire have or have not changed. Explain why.

3. Write a paragraph to answer this question: How difficult is the job of managing wildland fire? Explain by giving at least 3 specific examples of things a fire manager has to do.